FRONTISPIECE

Boat and dredging equipment

THE UNIVERSITY OF ALBERTA

THE BENTHIC FAUNA OF THREE MOUNTAIN RESERVOIRS IN ALBERTA

by

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ABSTRACT

The macroscopic benthic faunal communities of three mountain reservoirs were investigated to ascertain the structures of these communities and to compare these with conditions shown by past studies. An intensive survey of one of the three reservoirs gives a relatively detailed picture of the effects of artificial regulation of lake level upon the benthic fauna.

A littoral maximum of benthic fauna does not occur; maximum abundance is found in the vicinity of the lower limit of water level fluctuation. Chironomid larvae dominate the benthic fauna in numerical abundance. Unlike other oligotrophy-typical reservoirs and mountain lakes which have been surveyed, the chironomid fauna consists in large part of the Tribe Chironomini, which in general, is characteristic of more eutrophy-typical situations.

Regulation of bodies of water such as lakes, results in a quantitatively and qualitatively reduced benthic fauna and the lower limit of fluctuation is a focal point for the distribution and abundance of much of this fauna.

ACKNOWLEDGEMENTS

For suggesting and supervising this problem, I wish to express appreciation to Dr. J. R. Nursall. His guidance and patience were most helpful in the preparation of this study. Thanks are due C. G. Paterson for his assistance in the field. It was a pleasure to work with fellow students, J. R. Carefoot and J. S. Nelson, during the field work.

I am indebted to Dr. S. S. Roback for his identifications of the chironomid larvae.

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Technical data regarding the reservoirs were given by Calgary Power Limited, in addition to accommodation while investigating Upper and Lower Kananaskis Lakes.

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I. INTRODUCTION

Changes in the balance of the components of benthic faunal communities are characteristic of artificially regulated aquatic habitats; artificial regulation of water levels is often associated with commercial power production which necessitates the regulation of the water level in a given lake according to the requirements of the power plant associated with that lake. This generally results in major alterations in the benthic fauna, of a qualitative and quantitative nature, which are most evident in the region directly subject to water level fluctuations, with less deleterious effects extending to all depths (cf. Grimås, 1961; Miller and Paetz, 1959; Rawson, 1958). Three such regulated environments were investigated during this study, Barrier Reservoir, Upper Kananaskis Lake, and Lower Kananaskis Lake; these reservoirs are located in the Rocky Mountain region of southwestern Alberta.

The reservoirs included in this study were previously investigated by various workers. It is the attempt of this study to compare the organization of the macroscopic benthic faunal communities as they exist in Upper and Lower Kananaskis Lakes at present, with the conditions prior to regulation, and to evaluate changes in Barrier Reservoir, which formerly existed as an unmodified river valley and was investigated immediately following its impoundment.

The study of the benthic faunal communities is part of an overall assessment of faunal conditions in the Kananaskis River drainage system, with major emphasis on changes in Barrier Reservoir since its impoundment in 1947, and to a lesser extent with changes in Upper and Lower Kananaskis Lakes. The results of this study yield a relatively detailed structure for benthic communities occurring under such conditions.

Data and samples were collected during the years 1960 to 1963 from Barrier Reservoir and during 1961 and 1962 from Upper and Lower Kananaskis Lakes. Field records and preserved material are at the Department of Zoology, University of Alberta, Edmonton, Alberta.

II. METHODS

The reservoirs studied included Barrier Reservoir, Lower Kananaskis Lake, and Upper Kananaskis Lake, all of which occur in the Kananaskis River Valley (Fig. 1).

Data were collected from June to September 1960, May to September 1961, March 1962, May to September 1962, March 1963, and June 1963.

Limnological measurements were taken weekly at two stations from Barrier Reservoir during the spring and summer months of 1960, 1961, and 1962; monthly measurements were obtained for Lower and Upper Kananaskis Lakes during 1961 and 1962. Temperature series were measured with a reversing thermometer for the major portion of the 1960 survey, the remainder of the temperatures were obtained with a Whitney underwater thermometer; conductivity measurements were taken with the same Whitney instrument; both temperature and conductivity measurements are based on electrical resistances. Oxygen content was determined by Miller's method (Miller, 1914). A Hellige comparator was used for determining pH, using phenol red-D as an indicator. An index of light penetration was obtained by taking Secchi's disc readings. Sedimentation samples were taken weekly in Barrier Reservoir during 1961 and 1962.

Bottom sampling was done with an Ekman dredge covering an area of 225 sq. cms. In 1960 a Petersen dredge,

covering an area of 662.25 sq. cms., was used in conjunction with the Ekman dredge, to observe the distribution of the bottom forms within the mud samples themselves.

Observations of exposed regions of Barrier Reservoir during periods of low water level augmented the dredge samples; samples of mud 225 sq. cms. in area were taken; observations were made of the suitability of the undersides of rocks, logs, roots, etc., as habitats for organisms usually occurring in aquatic environments.

Table I shows the numbers of samples taken throughout the present investigation.

Table I. The numbers of bottom samples taken during the study.

	1960	1961	1962	1963
Barrier Reservoir	233	292	330	25
Lower Kananaskis Lake	-	44	28	-
Upper Kananaskis Lake	-	26	26	-

The bottom samples were washed successively through a series of three copper-mesh screens attached to wooden frames based on Rawson's (1930) design. The uppermost screen consisted of 256 meshes per sq. in., the lower screens had 1024 and 1600 meshes per sq. in., respectively. The mud was washed with water lifted in pails from the reservoir in 1960. In 1961 and 1962 a garden hose was used to wash

dredgings and proved more effective in removing the mud and exposing the bottom organisms. This method proved least satisfactory for obtaining oligochaetes, which tended to become fragmented and ruptured.

The organisms were removed from the meshes using fine-pointed forceps, placed in glass vials, preserved in formalin (approx. 10%) or 70% alcohol, and labelled. It was noted that preservation in alcohol resulted in such marked contraction of the chironomid larvae that intestinal contents were exuded. In 1961 and 1962 formalin was used exclusively for preserving samples. The vials were labelled according to location and time; a record was kept of the depth from which the sample was taken, with some indication of the bottom type.

The preserved material was subsequently separated into its major components (chironomids, pisidia, oligochaetes, and miscellaneous groups) which were counted and weighed. Weights were determined in grams using a Spoerhase electrical balance. The chironomids were further sorted into individual species using a binocular microscope with a range from 15X to 100X magnifications. This latter procedure applied to representative samples from the various stations in Barrier Reservoir and to all of the samples obtained from Upper and Lower Kananaskis Lakes.

The chironomid species were identified by the author from larval material obtained in the dredgings, using

the keys of Johannsen (1937a; 1937 b); Brundin (1948), and Roback (1957). A representative sample of 18 larval species were sent to Dr. S. S. Roback for identification and the names suggested by him are used for these species.

III. PAST STUDIES

Investigations carried out previous to this study allow for observation of changes which have occurred in the three reservoirs and to note which characters have remained unchanged.

Barrier Reservoir was examined by D. S. Rawson (1948) the year it was filled, and by J. R. Nursall during 1947 to 1949 (Nursall, 1952). Lower Kananaskis Lake was examined by Rawson in 1936 and 1947 (Rawson, 1937, 1948); by R. B. Miller (1954) during dam construction; R. C. Thomas (1955) noted construction operations employed by Calgary Power in dam building and made a post-impoundment survey (Thomas, 1957). Upper Kananaskis Lake was examined by Rawson in 1936 and 1947 (Rawson, 1937, 1948).

IV. THE RESERVOIRS

The three reservoirs studied lie in the Kananaskis River valley in the eastern area of the Rocky Mountains in southwestern Alberta (Fig. 1). The reservoirs are connected by the Kananaskis River, which drains northward into the Bow River, which in turn flows eastward into the Saskatchewan system of the Hudson Bay drainage.

A drop of 1,325 feet from Upper Kananaskis Lake to the river mouth has been utilized by Calgary Power Ltd. with a series of reservoirs and electric generating plants. Water is stored in the reservoirs to give maximum annual flow for adjacent power plants and for subsequent power plants along the Bow River.

Nelson (1962) gives the following sequence of annual events for the reservoirs: normally, Upper Kananaskis Lake is the first to be lowered to meet downstream water commitments. When that reservoir nears its low water level, Lower Kananaskis Lake and Barrier Reservoir are lowered respectively. Prior to spring run-off, all three reservoirs are at their lowest levels for the year. They are raised during the period of high spring run-off (Figs. 2 and 3). This allows for the most efficient use of the water for generation of electric-power.

Table II adapted from Miller and Paetz (1959) and Nelson (1962) gives the original areas and depths of the

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

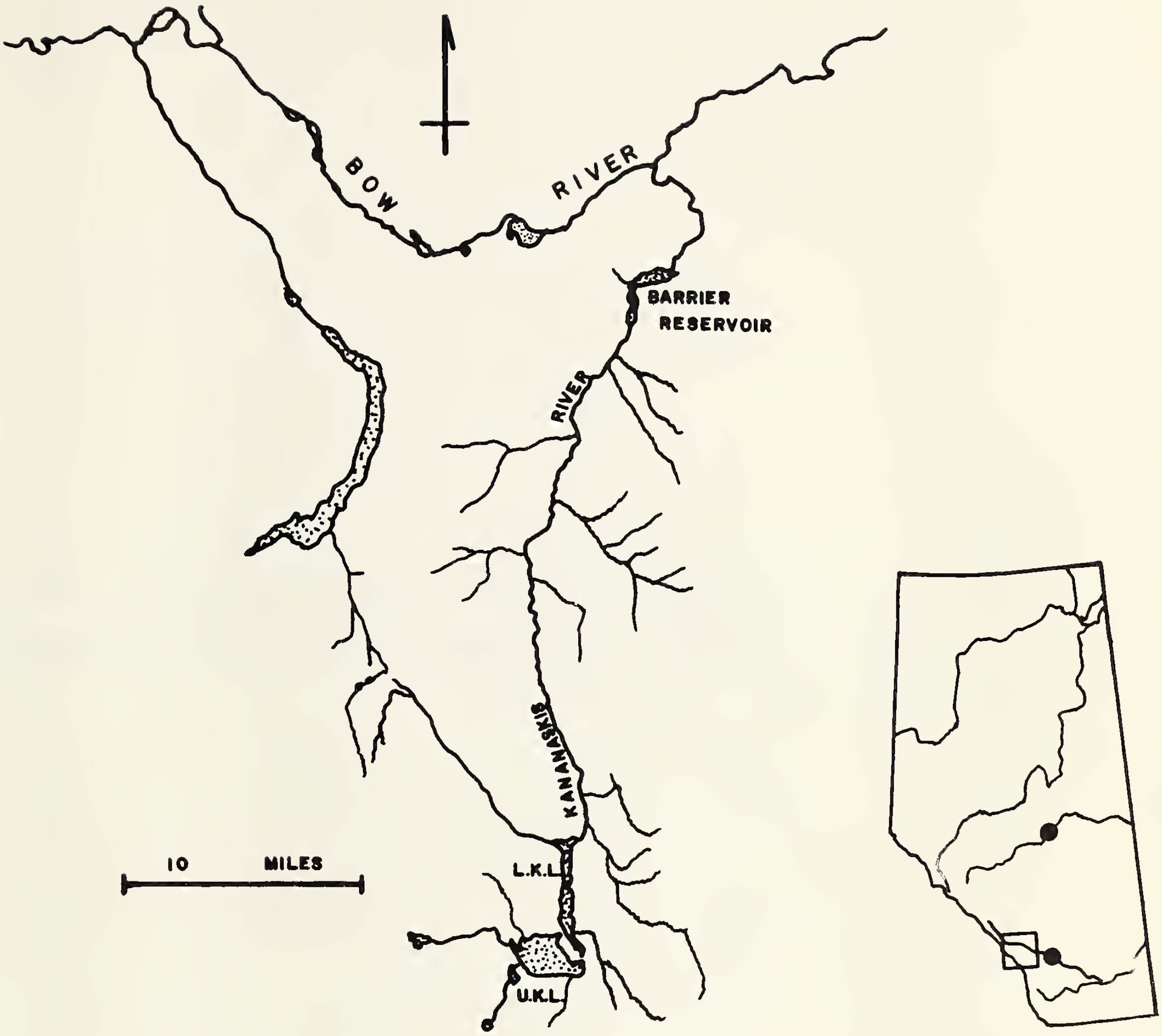
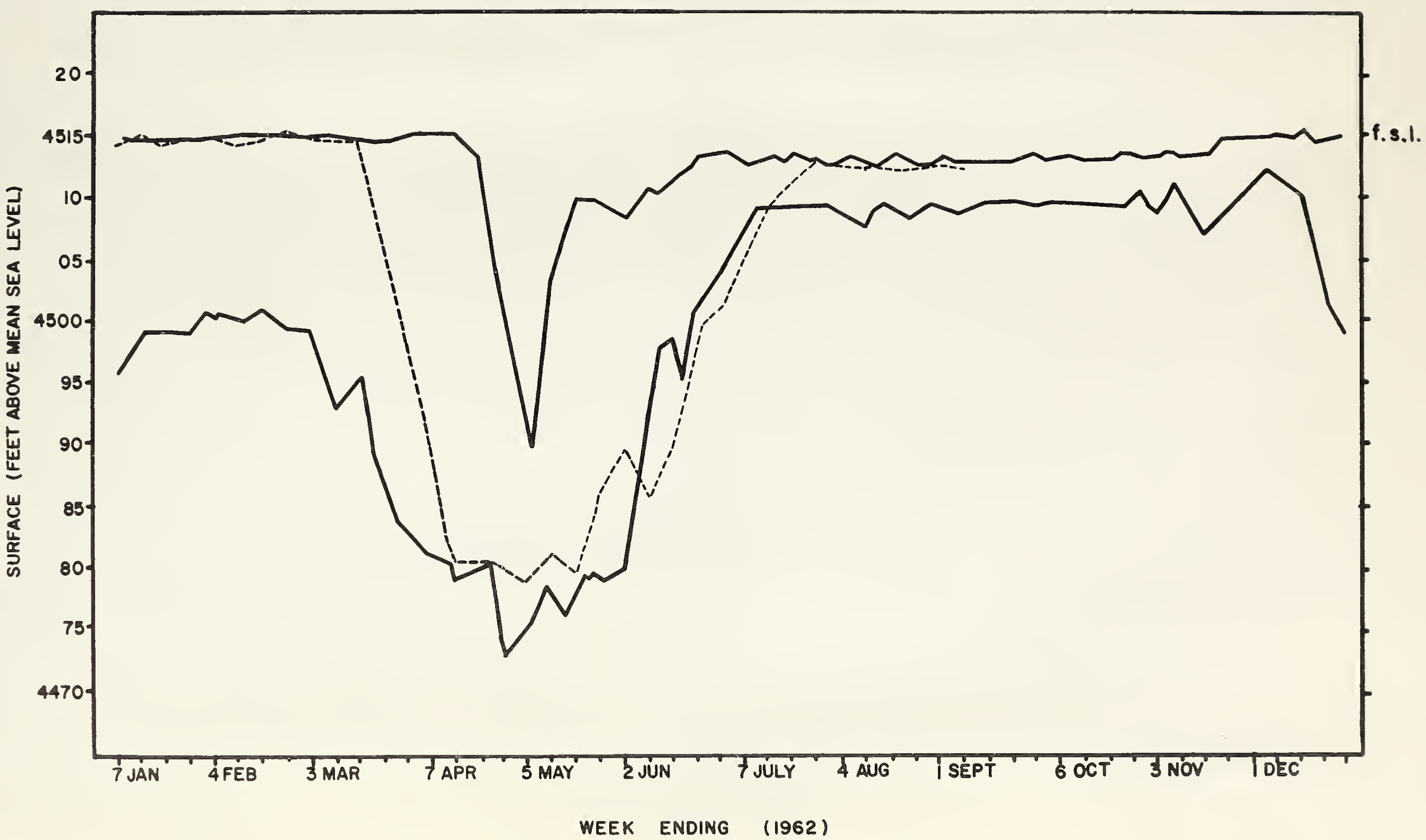


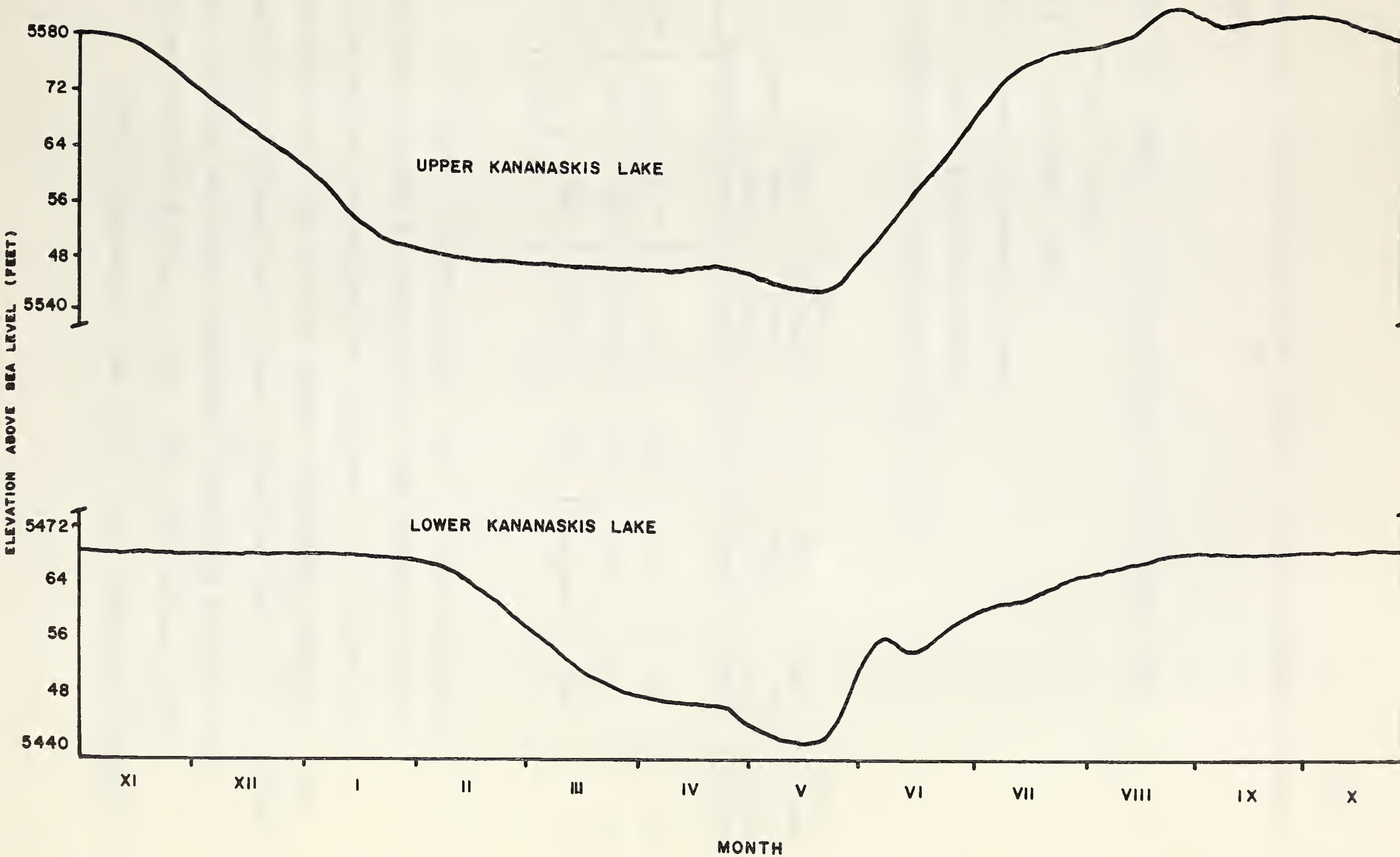
FIG. 1. Kananaskis River system, showing Barrier Reservoir, Lower Kananaskis Lake, and Upper Kananaskis Lake. Region of larger map indicated by rectangle on map of Alberta.

FIG. 2. Fluctuations in water level from 1951 - 1962 in Barrier Reservoir. Dotted line indicates fluctuation during 1962.



20
4515
10
05
4500
95
90
85
80
75
4470
f.s.l.
SURFACE (FEET ABOVE MEAN SEA LEVEL)
7 JAN
4 FEB
3 MAR
7 APR
5 MAY
2 JUN
7 JULY
4 AUG
1 SEPT
6 OCT
3 NOV
1 DEC
WEEK ENDING (1962)

FIG. 3. Fluctuation in water levels in Upper and Lower Kananaskis Lakes, 1961.



UPPER KANANASKIS LAKE
LOWER KANANASKIS LAKE
ELEVATION ABOVE SEA LEVEL (FEET)
5580
72
64
56
48
5540
5472
64
56
48
5440
XI
XII
I
II
III
IV
V
VI
VII
VIII
IX
X
MONTH

reservoirs, the new areas and depths, and the maximum drawdown limits.

Table II. Physical characteristics of the reservoirs.

f.s.l. = full supply level;

l.w.l. = low water level;

L.K.L. = Lower Kananaskis Lake;

U.K.L. = Upper Kananaskis Lake;

* = originally an unmodified river valley.

	Years Dammed	Original Area (acres)	New Maximum Area f.s.l. (acres)	Area at l.w.l. (acres)	Mean Depth f.s.l. (feet)	Maximum Depth (feet)	Maximum Drawdown (feet)
Barrier	1947	-- *	761	480	47	128	34
L.K.L.	1954	720	1600	700	47	138	43
U.K.L.	1936, 1942	1440	2113	1565	unknown	328	52

Figure 4 is an outline map of Barrier Reservoir indicating the shore topography and the dredging stations used during the investigation. Figures 5 to 13 are photographs depicting the diverse shore topography indicated. The suitability of these shore types for bottom fauna is discussed under littoral habitats. Additional data for Barrier Reservoir are given by Nursall (1949, 1952), and Nelson (1962).

Lower Kananaskis Lake is 44 miles upstream from the

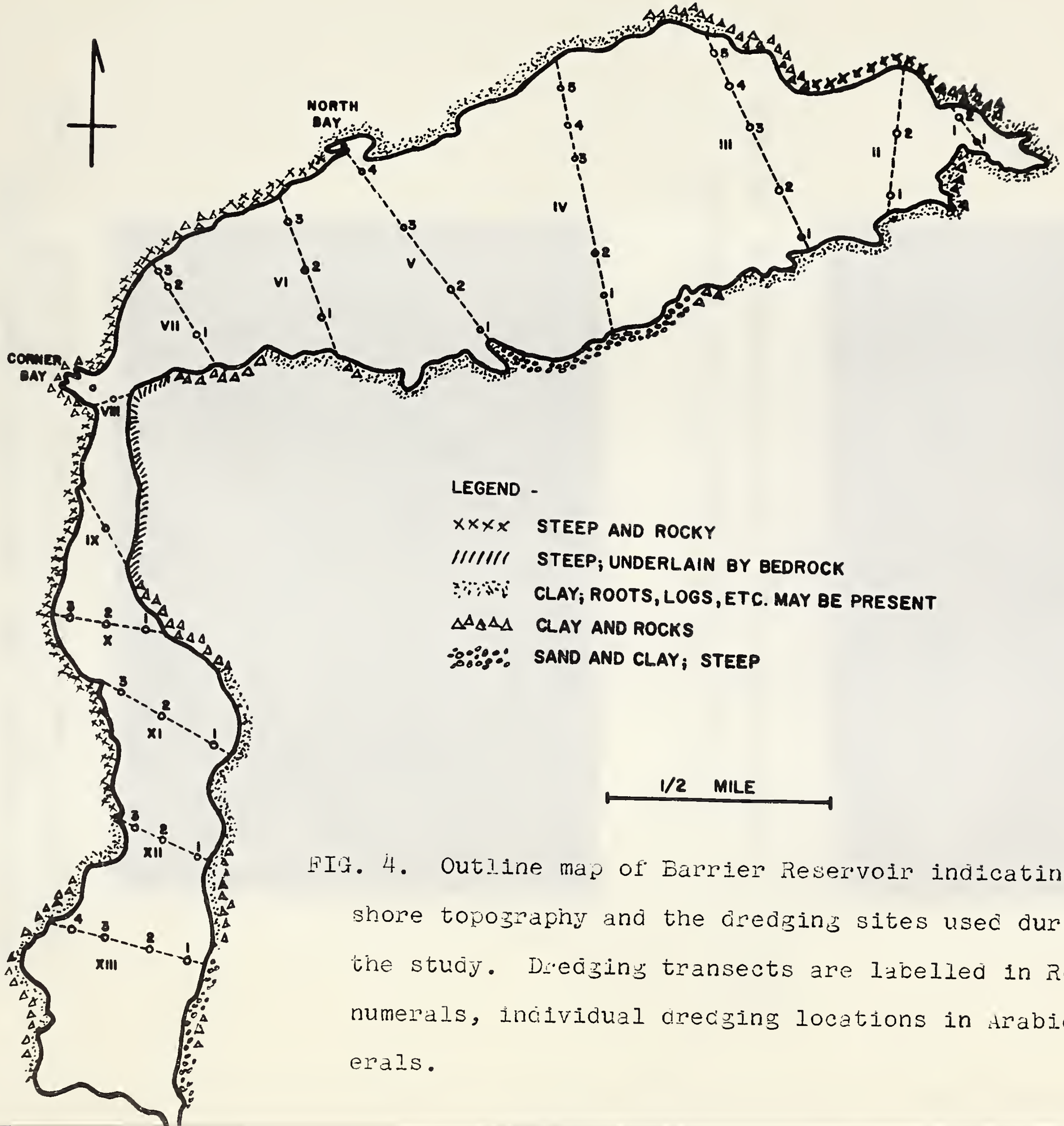


FIG. 4. Outline map of Barrier Reservoir indicating the shore topography and the dredging sites used during the study. Dredging transects are labelled in Roman numerals, individual dredging locations in Arabic numerals.

Fig. 5. Looking south towards inlet end of reservoir. Steep and rocky shore indicated to right of photo.

Fig. 6. Corner Bay. Steep and rocky shores to right and left of center, grading into clay and rocks in the bay.

Fig. 7. Shore, opposite Corner Bay. Exposed portions of bedrock. Note steepness.

Fig. 8. East shore, south of Corner Bay. Exposed bedrock with patches of clay.

Fig. 9. South shore, east of Corner Bay. Clay, with roots and logs.

Fig. 10. Looking south, at inlet end of reservoir shore bordered by rocks and clay, grading into clay.

Fig. 11. South shore, south of North Bay. Shore composed of sand and clay. The terracing caused by lowering of water level, at intervals.

Fig. 12. North shore, immediately west of dam. Clay and rocks predominate.

Fig. 13. Looking north towards dam and outlet. Steep and rocky dam, showing high water level and the extent of drawdown.

confluence of the Kananaskis and Bow rivers. The original lake level was raised in June 1955 from 5,431 feet elevation to a level of 5,469 feet at full supply level (f.s.l.). The drawdown limit permitted by the dam is 43 feet or a low water level (l.w.l.) of 5,426 feet. The maximum annual fluctuation exposes more than half the maximum area of the lake (Miller and Paetz, 1959). Figure 14 shows the shore condition of the Lower Kananaskis Lake.

Upper Kananaskis Lake is formed by the headwaters of the Kananaskis River and lies one mile upstream from Lower Kananaskis Lake. Data given by Rawson (1948) gives the original area of the lake as $2\frac{1}{4}$ sq. mi. at an altitude of 5,521 feet. A control dam was completed in 1936 allowing the level to rise 20 feet. A larger dam was completed in 1942 raising the water level to 5,580 feet (59 feet above the original level). This later dam allows a maximum draw-down of 52 feet. Figure 15 shows Upper Kananaskis Lake with rocky littoral region still exposed in August 1962.

Figure 16 indicates the orientation of Upper and Lower Kananaskis Lakes and shows exposed littoral areas.

Fig. 14. Lower Kananaskis Lake, looking south from Kent Creek.

Fig. 15. Upper Kananaskis Lake, looking south from Interlakes power plant.

Fig. 16. Looking southeast from Mount Indefatigable. Lower Kananaskis Lake to the left; Upper Kananaskis Lake to the right. Interlakes power plant in lower left.

V. PHYSICO-CHEMICAL CONDITIONS

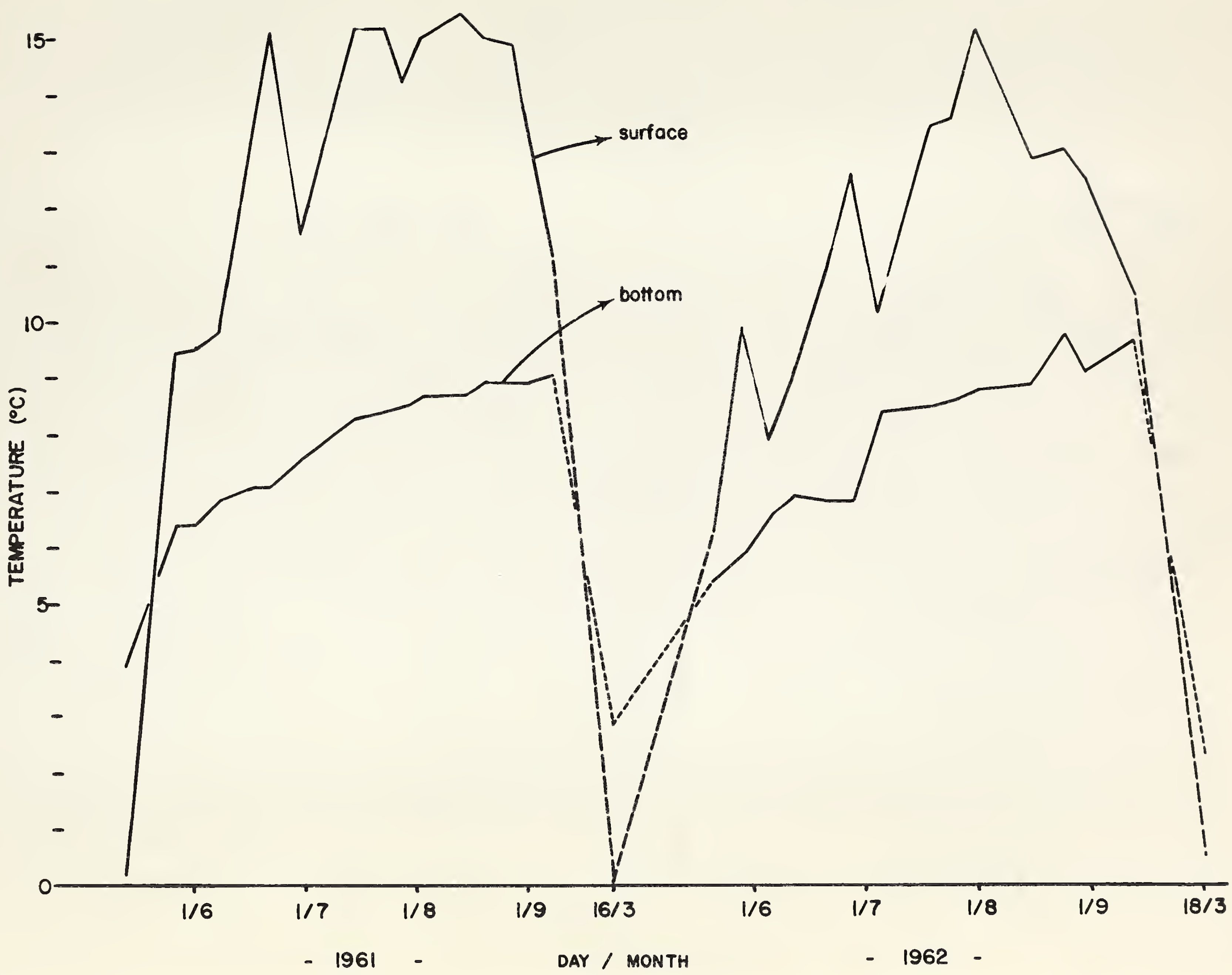
A. Temperature

Figure 17 is a graph of temperature conditions for Station I in Barrier Reservoir during two years. (Station I was identical in location to dredging site III-3 and the depth of the lake at this location was approximately 35 metres; Station II corresponds in position to dredging site X-2 with a depth of approximately 10.5 metres; cf. Fig. 4). The greatest temperature difference recorded in Barrier Reservoir was approximately 8°C (14.3° - 7.1°C) on June 23, 1961. Surface and bottom values come together in spring and early fall as turnover occurs; reversal in relative positions of cooler and warmer waters takes place during the winter months.

Figure 18 indicates the temperature conditions from Upper and Lower Kananaskis Lakes obtained in 1962. From the limited data, it appears that Lower Kananaskis Lake has a similar temperature regime to that of Barrier Reservoir, with bottom and surface temperatures roughly of the same order. Upper Kananaskis Lake is characterized by a cool profundal with the greatest temperature difference being approximately 9°C (13.3° - 4.2°C) on August 7, 1962; it is noted that a wide temperature difference is a consistent feature of Upper Kananaskis Lake, undoubtedly related to its relatively large hypolimnion.

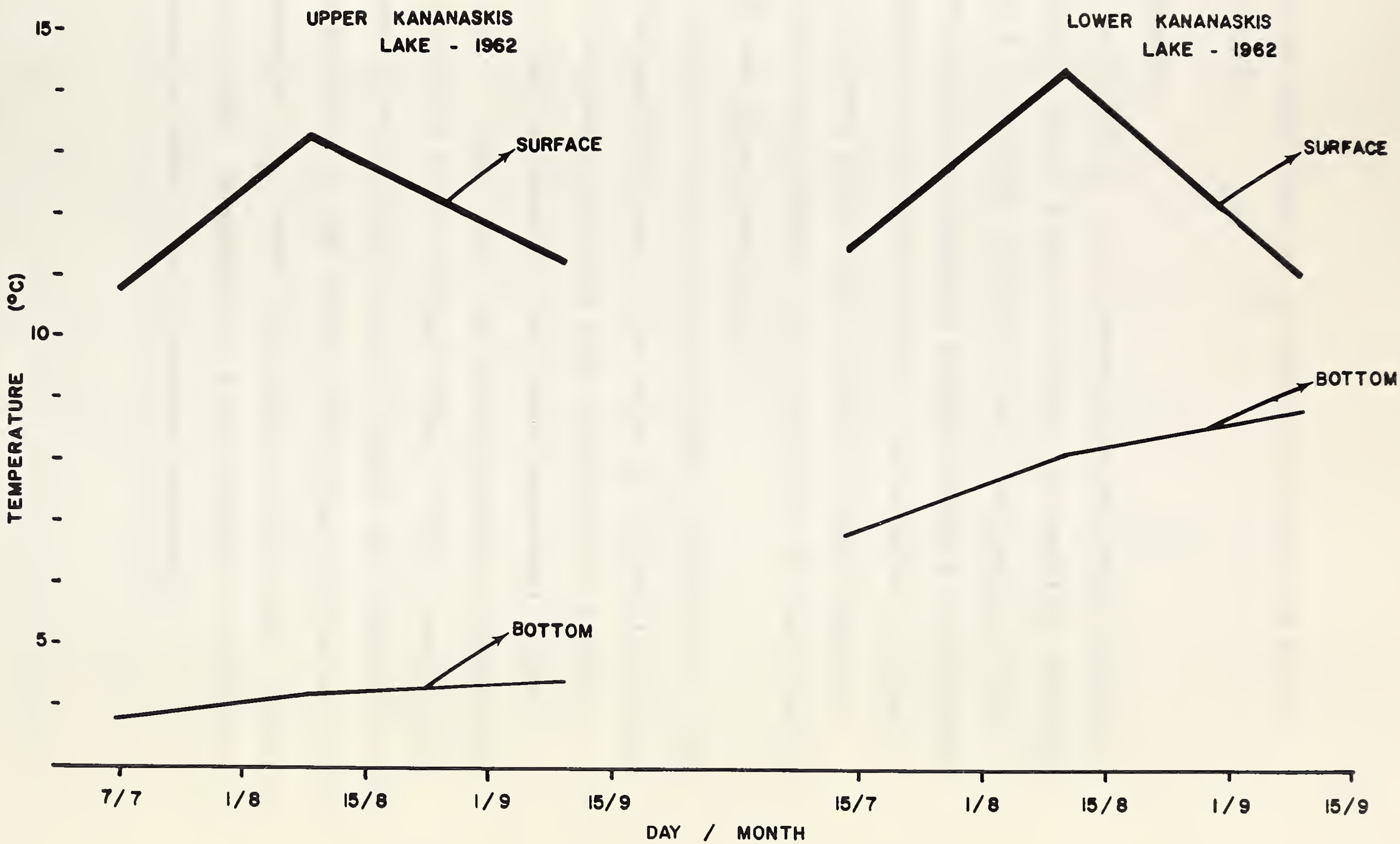
It does not appear that any changes of significance

FIG. 17. Temperature conditions at Station I in Barrier Reservoir.



15
10
5
0
TEMPERATURE (°C)
surface
bottom
1/6
1/7
1/8
1/9
16/3
1/6
1/7
1/8
1/9
18/3
- 1961 -
DAY / MONTH
- 1962 -

FIG. 18. Temperature conditons for Upper and Lower Kananaskis Lakes during 1962.


UPPER KANANASKIS
LAKE - 1962
LOWER KANANASKIS
LAKE - 1962
SURFACE
BOTTOM
SURFACE
BOTTOM
15
10
5
TEMPERATURE (°C)
7/7
1/8
15/8
1/9
15/9
15/7
1/8
15/8
1/9
15/9
DAY / MONTH

have occurred over the past 26 years in Upper and Lower Kananaskis Lakes.

B. Transparency

An index of light penetration has been obtained using Secchi's disc. Figure 19 gives the readings obtained at Station I in Barrier Reservoir over the period of this study. No consistent seasonal pattern emerges for changes in the degree of light penetration; the reservoir is much affected by strong winds which result in heavy loads of silt and clay being removed from the shores of the reservoir decreasing the light penetration.

Table III lists selected values obtained for Upper and Lower Kananaskis Lakes. The order of increasing transparency of the reservoirs has been suggested as Barrier Reservoir, Upper Kananaskis, and Lower Kananaskis Lakes (Nelson, 1962). That Upper and Lower Kananaskis Lakes are perhaps similar in their average index of light penetration is indicated from readings taken in August and September 1962, when Upper Kananaskis Lake shows increasing transparency while Lower Kananaskis Lake shows decreasing transparency. However, the degree of light penetration is much greater in Upper and Lower Kananaskis Lakes than in Barrier Reservoir.

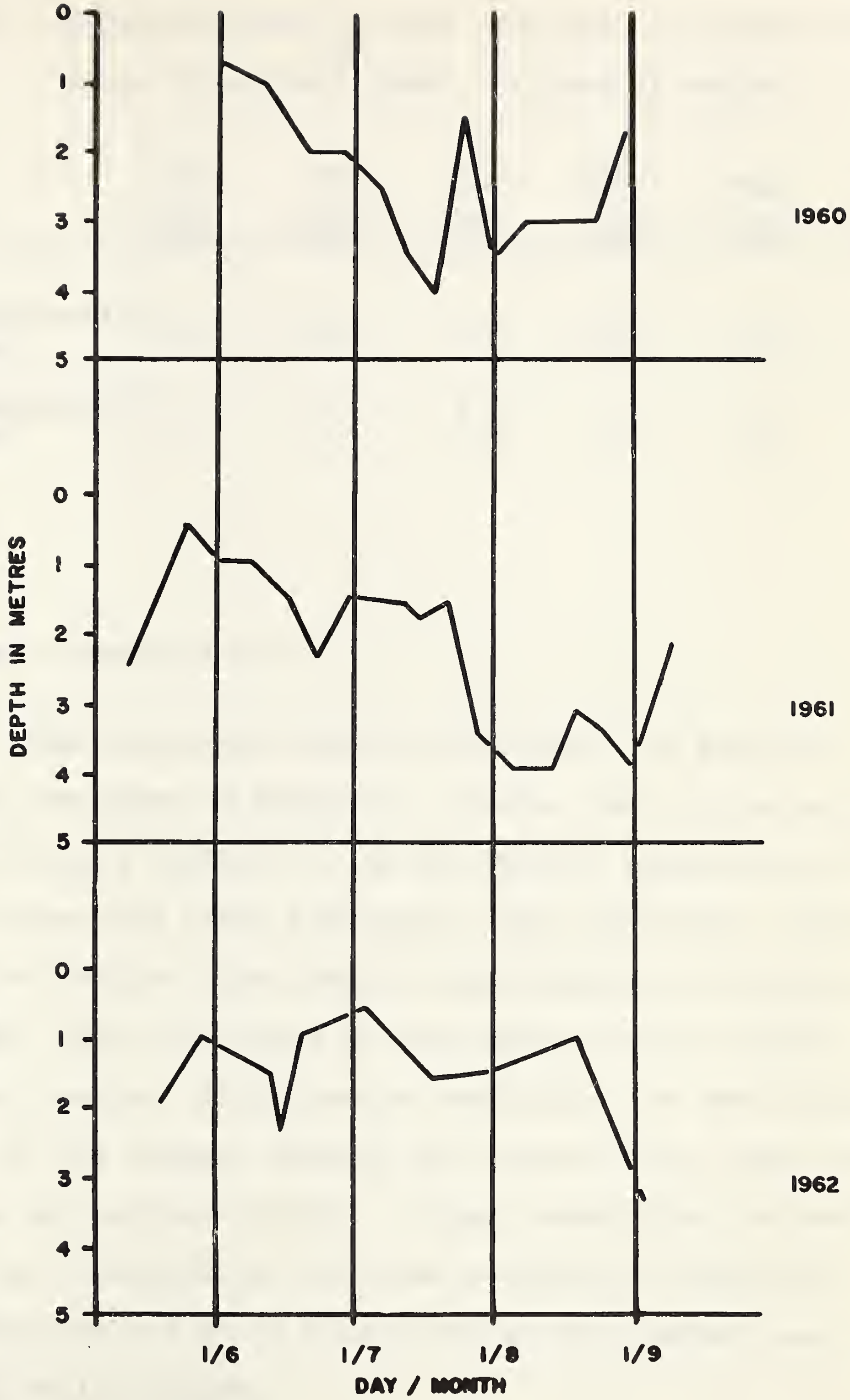


FIG. 19. Secchi's disc readings for Barrier Reservoir; obtained at Station I.

Table III. Selected Secchi's disc readings for Upper and Lower Kananaskis Lakes. Values in metres.

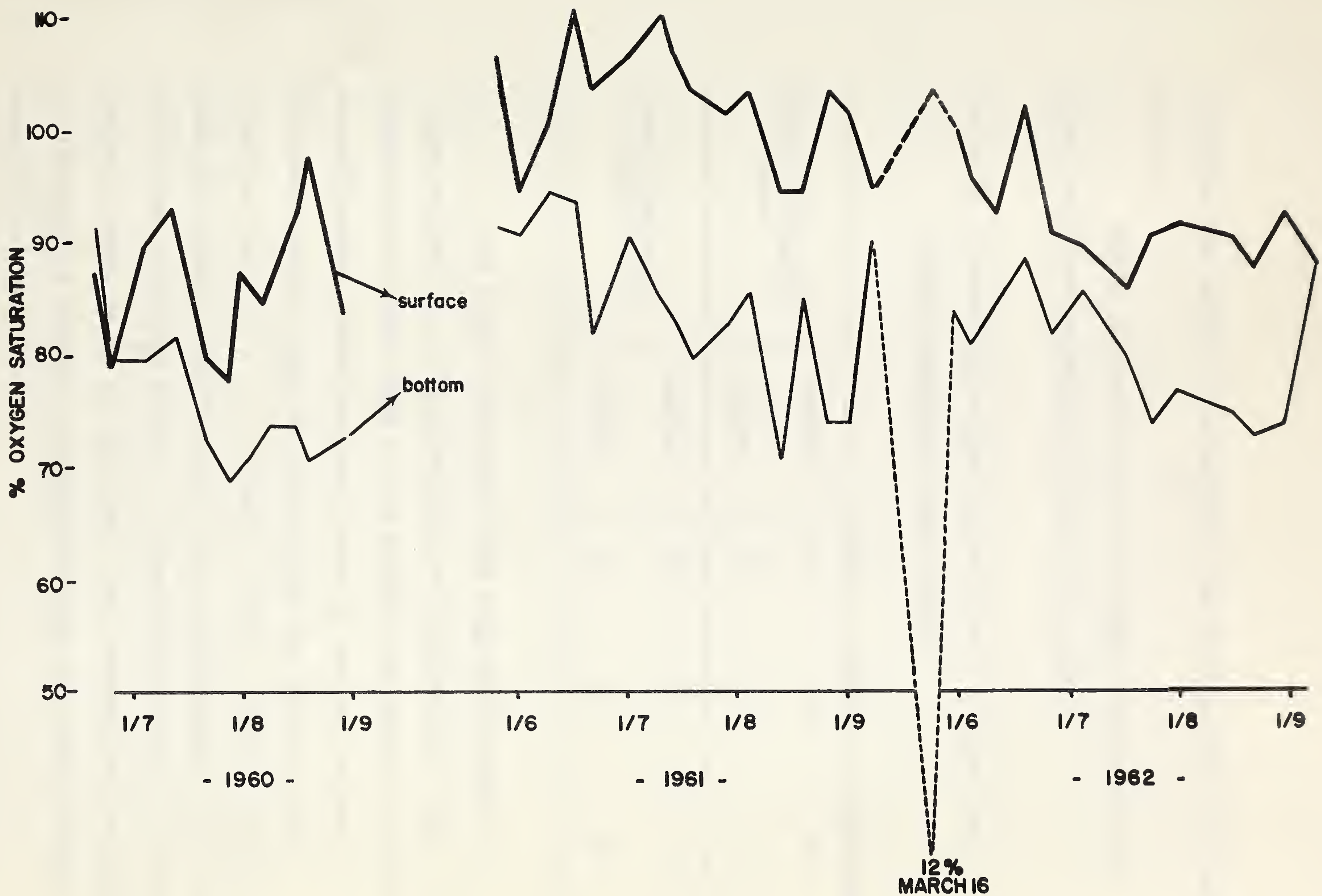
	June 1947	July 1947	July 1961	July 1962	Aug. 1962	Sept. 1962
Lower Kananaskis Lake	9.0	13.2	6.3	10.0	6.5	5.3
Upper Kananaskis Lake	6.0	8.5	3.3	3.0	5.5	8.5

C. Oxygen concentration

The percentage oxygen saturations for Barrier Reservoir are given in Figure 20. Values were corrected for altitude using a factor of 1.18 for Barrier Reservoir and 1.24 for Upper and Lower Kananaskis Lakes (Mortimer, 1956). Surface and bottom values tend to approximate one another in early June; high saturation of the surface waters exists throughout the year while bottom conditions are less saturated for much of the summer; surface and bottom values again approximate one another in fall. Oxygen saturation can become very low as evidenced by the value obtained for March 16, 1962, which was 12% at 35 metres and at this period ice cover was still present.

Fluctuations in oxygen values during the summer months may be attributed to periods of strong winds which

FIG. 20. Percent oxygen saturation for Barrier Reservoir obtained at Station I. (Abscissa: Day / Month)



110-
100-
90-
80-
70-
60-
50-
% OXYGEN SATURATION
surface
bottom
1/7
1/8
1/9
1/6
1/7
1/8
1/9
1/6
1/7
1/8
1/9
- 1960 -
- 1961 -
- 1962 -
12 %
MARCH 16

increase the amount of saturation for both surface and bottom waters.

Table IV gives values of oxygen saturation for Upper and Lower Kananaskis Lakes during 1962.

Table IV. Percentage oxygen saturations for Upper and Lower Kananaskis Lakes, 1962.

		July	August	September
Upper Kananaskis Lake	surface	93	98	82
	bottom	85	74	74
Lower Kananaskis Lake	surface	94	91	93
	bottom	83	74	56

All three reservoirs have high percentages of oxygen saturation, characteristic of oligotrophic lakes. No assessment has been made of the extent and nature of micro-stratification which has been shown by various workers to play an important role in determining the bottom types of organisms (see Brundin, 1951). Brundin points out that the oxygen concentration of the hypolimnial bottom water can become a minimum factor for some bottom animals in oligotrophic lakes, while at the same time, conventional methods of determining oxygen concentration show the bottom waters to have high oxygen values.

Table V. Hydrogen ion concentration in Barrier Reservoir, Lower Kananaskis Lake (L.K.L.), and Upper Kananaskis Lake (U.K.L.). * denotes values averaged from several readings.

	BARRIER		L.K.L.		U.K.L.	
	surface	bottom	surface	bottom	surface	bottom
1936			8.1	7.7	8.0	7.7
June 1947	7.9*	7.8*				
Aug. 1947	8.1*	7.8*	8.2	7.9	8.1	7.6
June 1961	8.2*	8.1*	8.0*	7.7*		
July 1961	8.2*	7.9*	8.2*	8.2*	7.9	7.6
Sept. 1961	7.9*	7.9*				
July 1962	7.9*	7.8*	7.8	7.7	7.9	7.6
Aug. 1962	8.2*	7.9*	8.0	7.6	7.8	7.6
Sept. 1962	8.4	8.5	8.4	7.7	8.0	7.4

D. Hydrogen ion concentration

The Kananaskis River system is characterized by generally being alkaline in nature. Values for pH ranging from 7.4 to 8.5 have been obtained for Barrier Reservoir.

Table V lists values for all three reservoirs.

E. Specific conductance

Conductance values show a wide range of values throughout the season in Barrier Reservoir. Low spring readings were obtained in 1961 and 1962 with a tendency to highest values in mid-summer; the lowest values were obtained under winter conditions. This arrangement of values can be explained by spring run-off raising the electrolyte content of the reservoirs followed by a quantitative decrease towards fall, and with lowest values in the winter. Figure 21 is a graph of the values obtained from Barrier Reservoir. Values obtained from Upper and Lower Kananaskis Lakes in 1962 are contained in Table VI.

Table VI. Specific conductance for Upper and Lower Kananaskis Lakes during 1962. Values in micromhos.

Upper Kananaskis	surface	bottom
July 6	118	125
August 7	152	108
September 8	151	153
Lower Kananaskis	**surface**	**bottom**
July 5	168	161
August 9	182	163
September 9	178	171

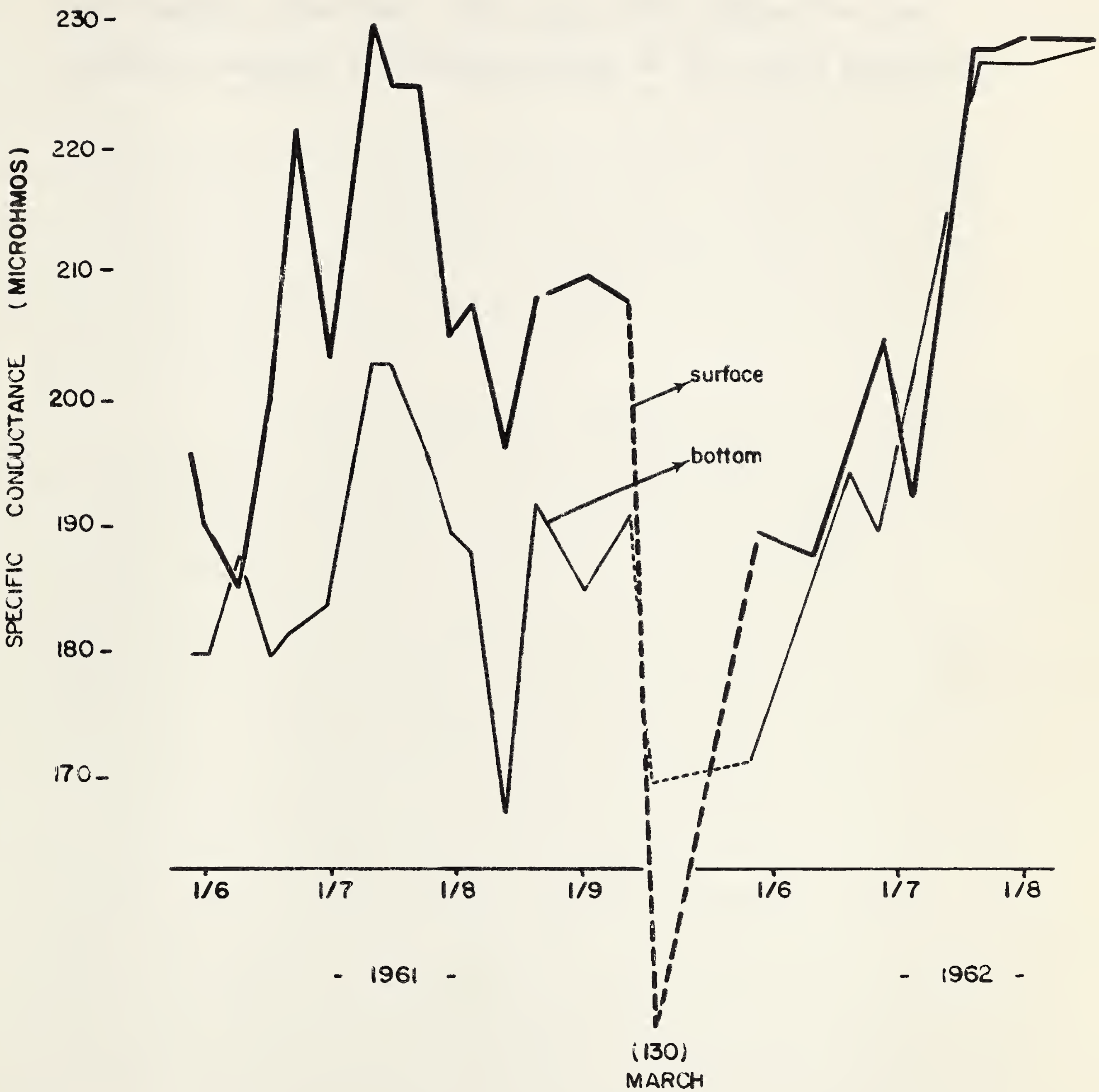


FIG. 21. Specific conductance for Barrier Reservoir; obtained from Station I. (Abscissa: Day / Month)

It can be seen that the order of increasing conductance is Upper Kananaskis Lake, Lower Kananaskis Lake, and Barrier Reservoir; this same order exists for the relative amounts of drainage areas of the three reservoirs.

VI. BOTTOM FAUNA

A. General.

Consideration will be given primarily to the bottom fauna of Barrier Reservoir and the effect of regulation of water levels upon this fauna. Comparisons will be drawn with Upper and Lower Kananaskis Lakes; reference to other studies, especially those on Swedish lakes, will also be made.

The groups present in Barrier Reservoir comprise members of the Insecta, Crustacea, Hydracarina, Mollusca, Oligochaeta, Hirudinea, Nematoda, Porifera, and Hydrozoa. These are the groups which have been retained in the sifting process; not included are the smaller forms which pass through the screens. Table VII lists the organisms found in approximately 850 dredging samples. In addition, hydras are commonly found attached to sedimentation sampler bottles, including those in the deeper portions of the lake. These have been identified as *Hydra oligactis* Pallas. Only the three major groups, chironomids, molluscs, and oligochaetes, are included in the distribution analysis of the bottom fauna as they account for more than 95% of the total bottom fauna.

Occurrence and distribution of the organisms are related to various "depth zones"; these include the Littoral Zone which is further divided into Upper Littoral (0 - 5 m.)

Table VII. Numbers of miscellaneous organisms obtained during 1960, 1961 and 1962 in Barrier Reservoir, from dredging samples (approximately 850 samples).

INSECTA:	
Empidid larvae	39
Ceratopogonid larvae	37
Tipulid larvae	6
Other dipterous larvae	11
Mayfly larvae	14
Stonefly larvae	2
Caddis fly larvae	2
OTHERS:	
Mites	85
Gammarids	1
Nematodes	3
Sponges	9
Unidentified	5
TOTAL	214

and Lower Littoral (5.5 - 15 m.). The bottom of the Littoral Zone may consist of sand, stone, clay, or a combination of these components; this zone is subject to water level fluctuation (down to a depth of approx. 10 m. in Barrier Reservoir); higher aquatic vegetation is absent though occasional patches of mosses and algae are to be found. The other major zone is the Profundal Zone which has arbitrarily been divided into Upper Profundal (15 - 20 m.) and Lower Profundal (20.5 m. - bottom) for this study; the bottom is generally of clay.

The fauna of Barrier Reservoir was studied by Nursall from 1947 to 1949, following impoundment of the river. At this time the bottom fauna consisted of the larvae of Chironomidae, Oligochaeta, Gammarus, and the larvae of several dipterous families other than the Chironomidae. The numerical abundance of the chironomids are compared with the other benthic forms in Table VIII.

The terms herein, molluscs and pisidia, refer to species of the genus Pisidium.

Table VIII. Numbers of Chironomidae compared to numbers of other benthic organisms in Barrier Reservoir 1947 - 49 (from Nursall, 1952).

Year	Sampling Period	No./m^2 Chironomidae	No./m^2 All Others	No./m^2 Total	% of Chironomidae
1947	June	16	46	62	25.8
	July	123	128	257	49.0
	Aug.	335	3	338	99.2
	Sept.	390	26	416	93.6
1948	Jan.	1270	6	1276	99.6
	June	134	15	149	89.9
1949	Jan.	776	4	780	99.6
	June	381	17	348	95.7
Totals		3425	245	3670	88.0
	Total excluding June, July, 1947				98.0

The chironomids at this time accounted for 98% of the total bottom fauna. In subsequent years this dominance by the chironomids was reduced as indicated in Table IX.

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Table IX. Percentage composition of the benthic fauna of Barrier Reservoir 1960 - 62. Percentages derived from numerical abundance of the major groups.

Year	% Chironomidae	% Mollusca	% Oligochaetes
1960	68.2	15.9	15.9
1961	70.3	20.7	9.0
1962	63.9	25.6	10.5
Mean	67.4	21.2	11.4

As was predicted by Nursall, molluscs have invaded Barrier Reservoir from Lower Kananaskis Lake which lies upstream, 32 miles, from Barrier Reservoir. Molluscs are now more abundant than the oligochaetes, accounting for 21.2% of the fauna while the oligochaetes account for 11.4%.

Changes in the standing crop of bottom fauna are also in evidence as shown in Table X.

Table X. Comparison of the standing crops of bottom fauna of Barrier Reservoir. Values are given as dry weights in kgm/ha. (Figures for period 1947 - 49 from Nursall, 1952).

Sept. '47	Jan. '48	June '48	Jan. '49	June '49
1.94	18.82	1.83	2.09	1.81

Table X. (continued).

June-Aug. '60	June-Sept. '61	Mar. '62	June-Sept. '62	Mar. '63
2.60	5.05	15.34	6.71	8.38

Substantial increases are noted in the summer crops of benthic productivity ; this was also predicted by Nursall (1949). Rawson (1955) advances the formula

$$f = \frac{69.2}{(d-5)^{0.778}}$$

for calculating standing crops from mean depth; where f is the standing crop in kgm. per ha. and d is the mean depth in metres. This formula gives a value of 9.47 kgm/ha for a lake with mean depth 14.4 m., which is the mean depth for Barrier Reservoir. The values obtained for standing crops during this study (cf. Table X), although somewhat smaller than that obtained from Rawson's formula, are reasonable, as the formula was based on data from lakes with stable littoral regions. It is the littoral region which tends to be the zone of highest productivity, and in Barrier Reservoir, is relatively unproductive.

The values for Barrier Reservoir were calculated from wet weights; the weight of the mollusc shells was deducted (the weight deducted was 60% of the total weight

of the molluscs; this percentage was determined by comparing mollusc weights before and after the shell was removed); the remaining total weight was then converted into a dry weight reading by employing a conversion factor of 0.15. Rawson (1930) gives the portion of total mollusc weight of the shell as 75%; he also suggests values of 0.20 to 0.15 for converting wet weight to dry weight (p. 109). A series of wet weights compared to their dry weights on samples from Barrier Reservoir suggested the suitability of the figure 0.15.

The annual production of bottom fauna of Barrier Reservoir compared to that in Lake Simcoe is given in Table XI.

Lake Simcoe drains into Georgian Bay through the Severn River, in Ontario. It is situated 40 miles north of Toronto and was investigated by Rawson from 1926 to 1928. The area of the lake is 280 sq. mi., its average depth is 17 metres (54 feet), and its maximum depth is 44 metres. The water is alkaline, pH 8.1, and fairly well oxygenated.

By studying the annual growth of the bottom organisms and using data on the rate of growth, the increase due to reproduction, an estimate of annual production of a given benthic form can be calculated from the weights of this form for a given period of the year. Lundbeck's determinations (from Rawson, 1930) of yearly productivity are based on weight values obtained during the summer months in the following manner: three times the summer average for chironomid larvae,

Table XI. Annual production of bottom fauna of Lake Simcoe and Barrier Reservoir. (Values for Lake Simcoe from Rawson, 1930).

	Organism	Average amt. of fauna May-October. kgm/ha	Rate of productivity (after Lundbeck)	Annual production kgm/ha
SIMCOE	Chironomid larvae	8.06	x 3	24.18
	Mollusca	2.22	x 1/3	0.74
	All others	2.10	x 2	4.20
	TOTALS	12.38		29.12
	Organism	Average amt. of fauna June-Sept. ('61, '62). kgm/ha	Rate of productivity (after Lundbeck)	Annual production kgm/ha
BARRIER	Chironomid larvae	6.07	x 3	18.21
	Molluscs	1.98	x 1/3	0.66
	Oligochaetes	0.18	x 2	0.36
	TOTALS	8.23		19.23

one third for the molluscs, and twice for the remainder.

Barrier, having a mean depth of 14.4 metres could be expected to have a higher production of bottom fauna per hectare than does Lake Simcoe with a mean depth of 17 metres. Under similar conditions the values calculated for standing crops in lakes with these dimensions are 9.47 kgm/ha for Barrier Reservoir (as shown on page 39) and 7.41 kgm/ha for Lake Simcoe. The discrepancy between these values is alloted in part to the deleterious effect of water level fluctuation in Barrier Reservoir. A value of 15.81 kgm/ha could be expected from a lake of mean depth 14.4 metres as indictated below, using Lake Simcoe as a standard:

$$\frac{7.41}{12.38} = \frac{9.47}{X}$$

$$X = 15.81$$

Thus Barrier Reservoir has a standing crop of bottom fauna with a value of 52.1% of the value for an unregulated lake of similar morphometry.

Lundbeck, (from Rawson, 1930) has calculated the distribution of bottom fauna in a typical eutrophic lake (Plöner See), and offered a diagrammatic representation of the limiting factors. This diagram is shown in Figure 22 (after Rawson, 1930), with the distribution of bottom

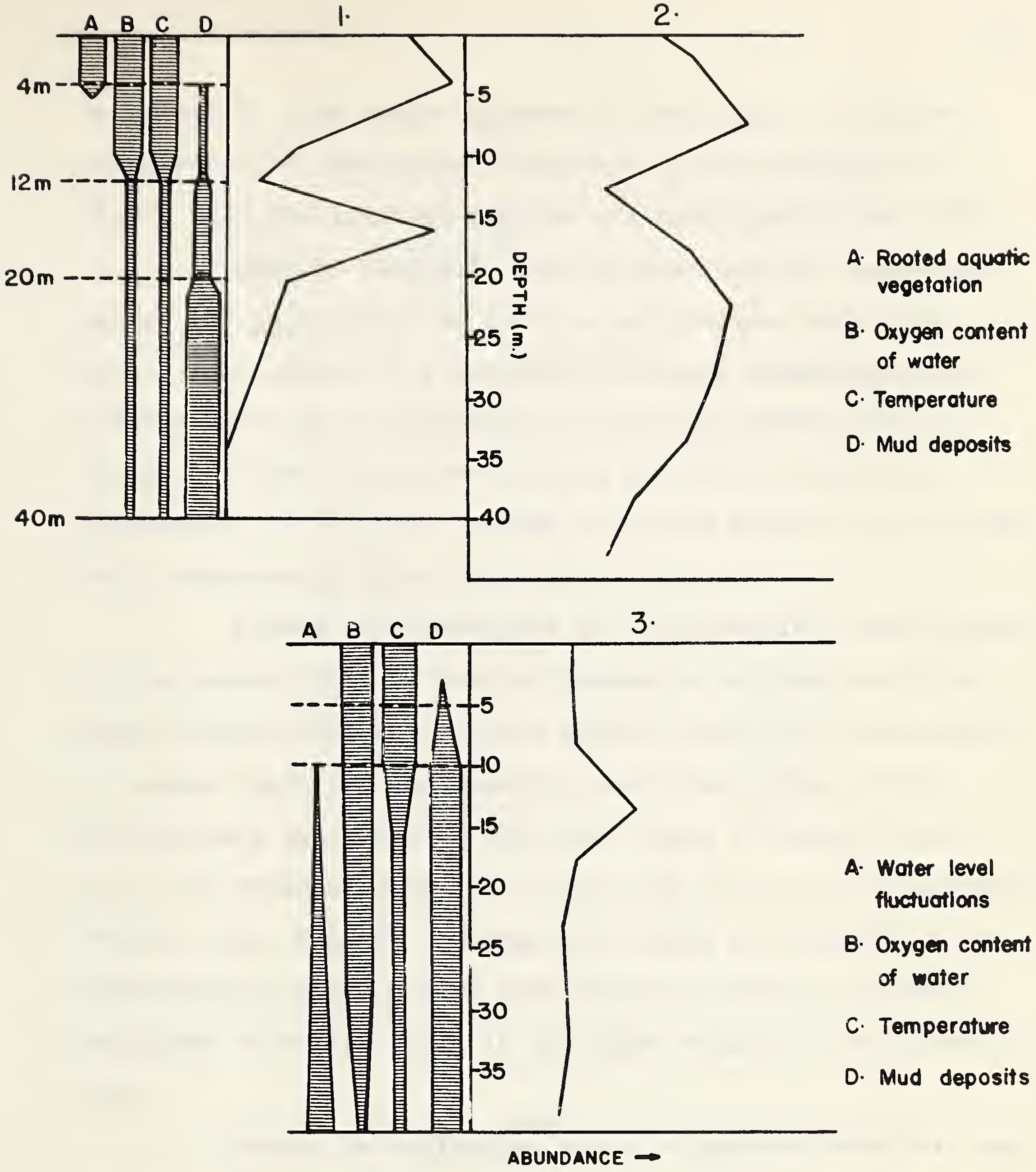


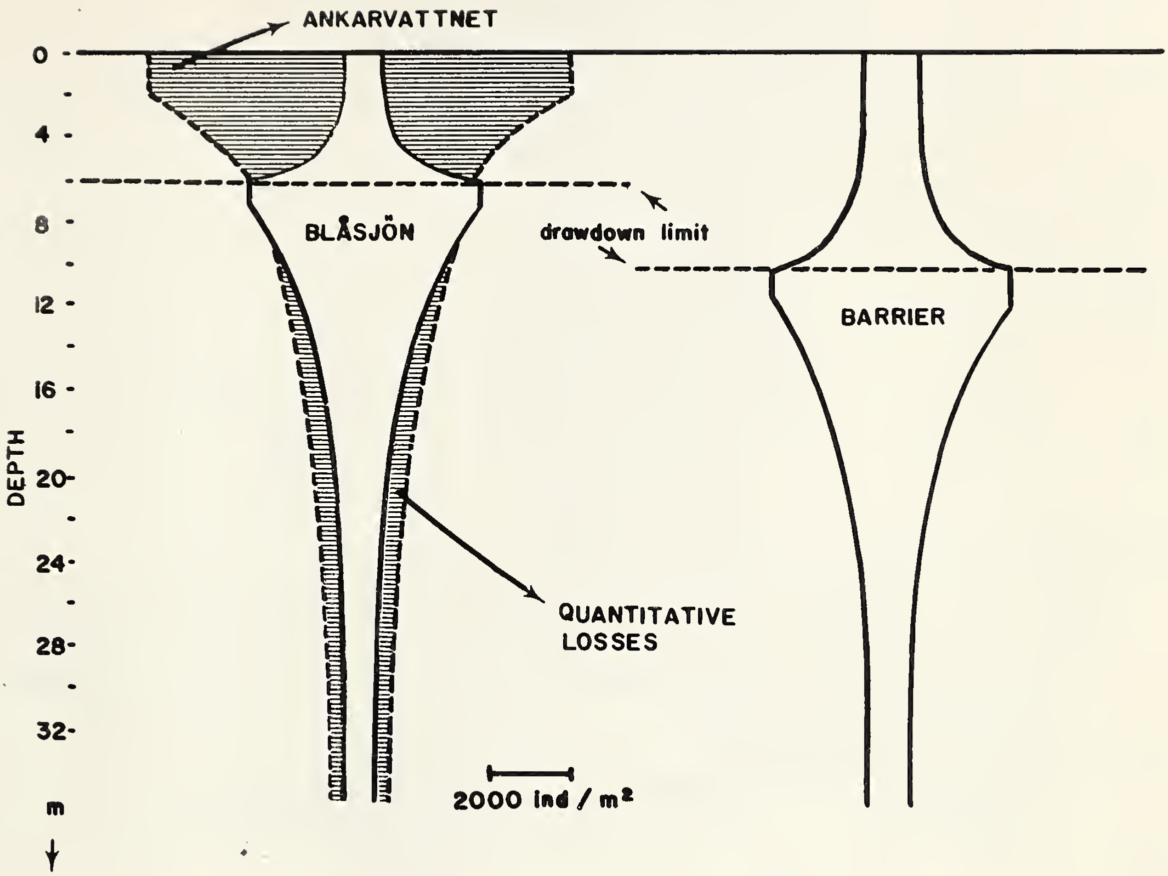
FIG. 22. Vertical distributions of total bottom fauna for a typical eutrophic lake (1. Plöner See), Lake Simcoe (2.), and Barrier Reservoir (3.). Diagrammatic representations of the limiting factors are given.

organisms in Lake Simcoe plotted to the right. A similar representation for Barrier Reservoir is also included in Figure 22. The limiting factors are indicated to the left.

Barrier Reservoir lacks higher aquatic vegetation; mosses and Chara occur in local concentrations about the lake. The absence of a developed littoral vegetation concomitant with the fluctuation of the water level plus the exposure of the bottom for certain periods of the season suppresses the littoral maximum of bottom fauna, this maximum being characteristic of unregulated lakes.

Figure 23 illustrates the bathymetrical distribution of the bottom fauna of Barrier Reservoir and compares this distribution with that of Lake Blåsjön and Lake Ankarvattnet in Sweden (data for the Swedish lakes from Grimås, 1961). The greatest abundance of the total fauna of Barrier lies below the drawdown limit as is also the case for the regulated Swedish lake, Blåsjön. Unregulated lakes as exemplified by Ankarvattnet (also compare Lake Simcoe), have the greatest abundance of bottom fauna in the upper region of the littoral zone.

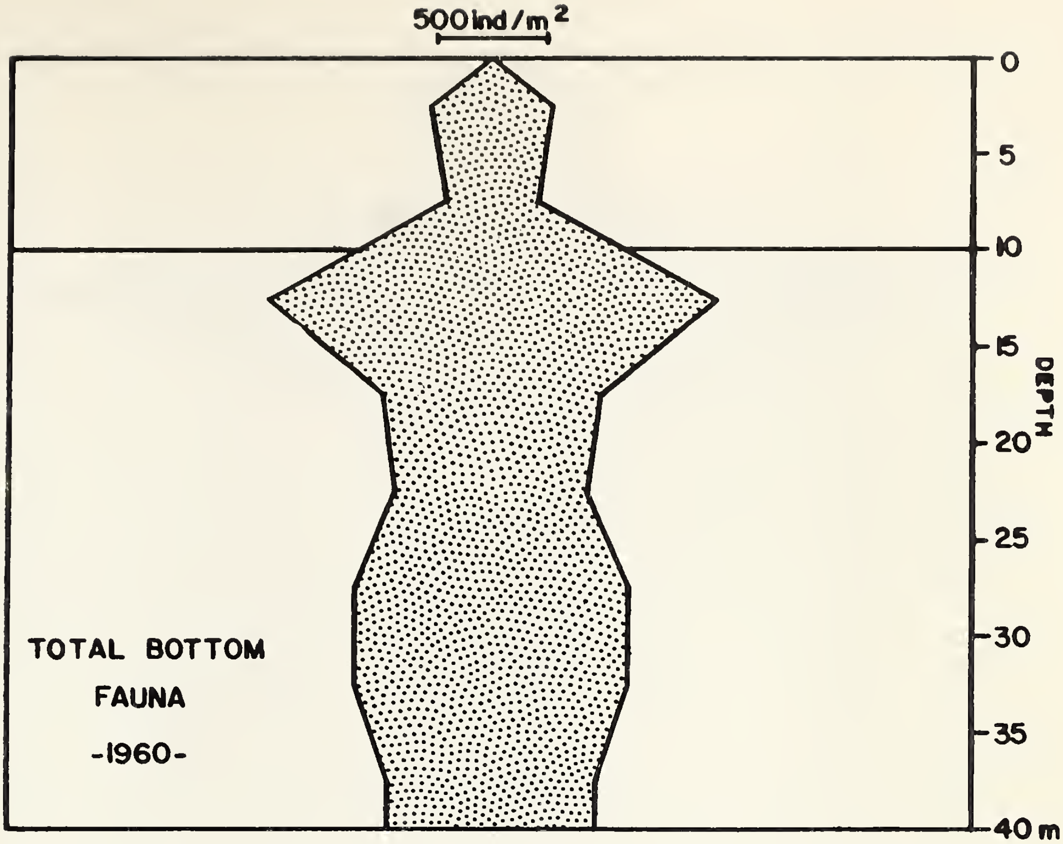
Annual variations such as occur in Barrier Reservoir can be seen in Figures 24, 25, and 26; Table XII summarizes the data. All groups have a maximum numerical abundance below the drawdown limit, with the littoral zone occupied almost exclusively by the chironomid fauna. The abundance of



Quantitative losses due to effect of regulation. Blåsjön and Ankarvattnet had similar populations prior to regulation of Blåsjön.

FIG. 23. Bathymetrical distribution of the total bottom fauna in Lakes Blåsjön and Ankarvattnet compared with that in Barrier Reservoir.

FIG. 24. Bathymetrical distribution of the total bottom fauna and its components for Barrier Reservoir, 1960.


500 ind/m²
0
5
10
15
20
25
30
35
40 m
DEPTH
TOTAL BOTTOM
FAUNA
-1960-

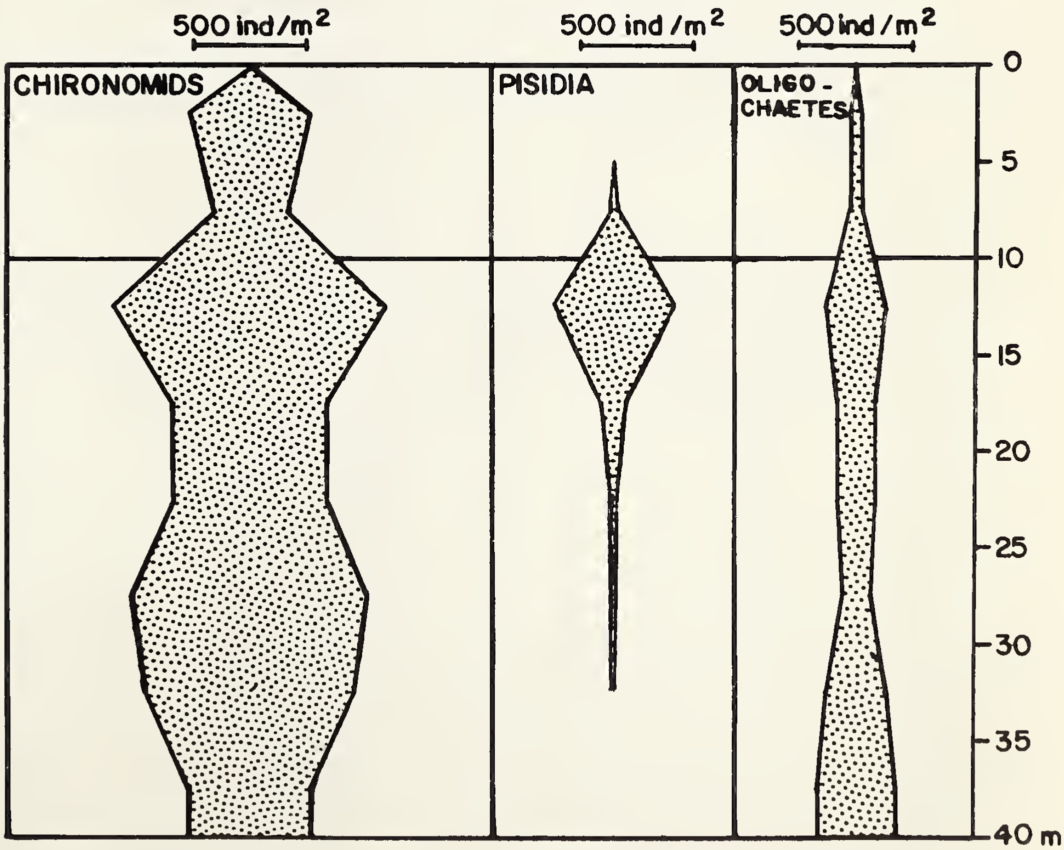
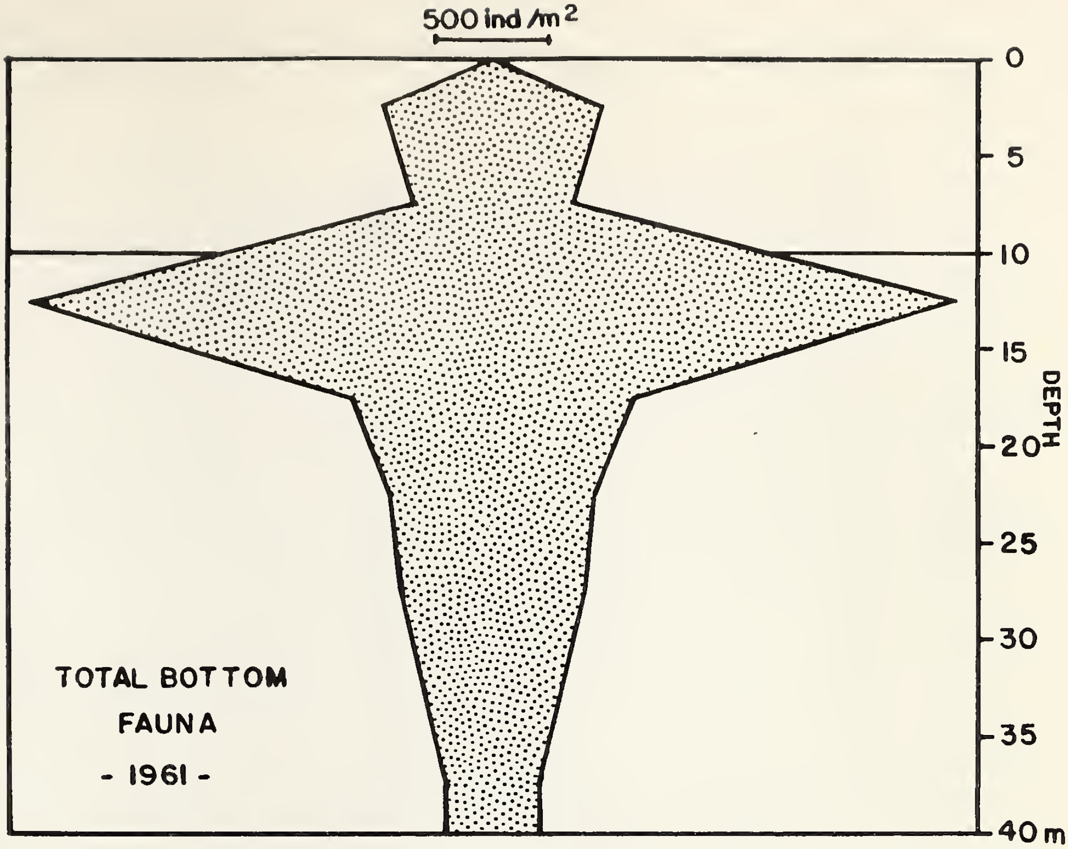

500 ind/m²
500 ind/m²
500 ind/m²
CHIRONOMIDS
PISIDIA
OLIGO-
CHAETES
0
5
10
15
20
25
30
35
40 m

FIG. 25. Bathymetrical distribution of the total bottom fauna and its components for Barrier Reservoir, 1961.


500 ind/m2
0
5
10
15
20
25
30
35
40 m
DEPTH
TOTAL BOTTOM
FAUNA
- 1961 -

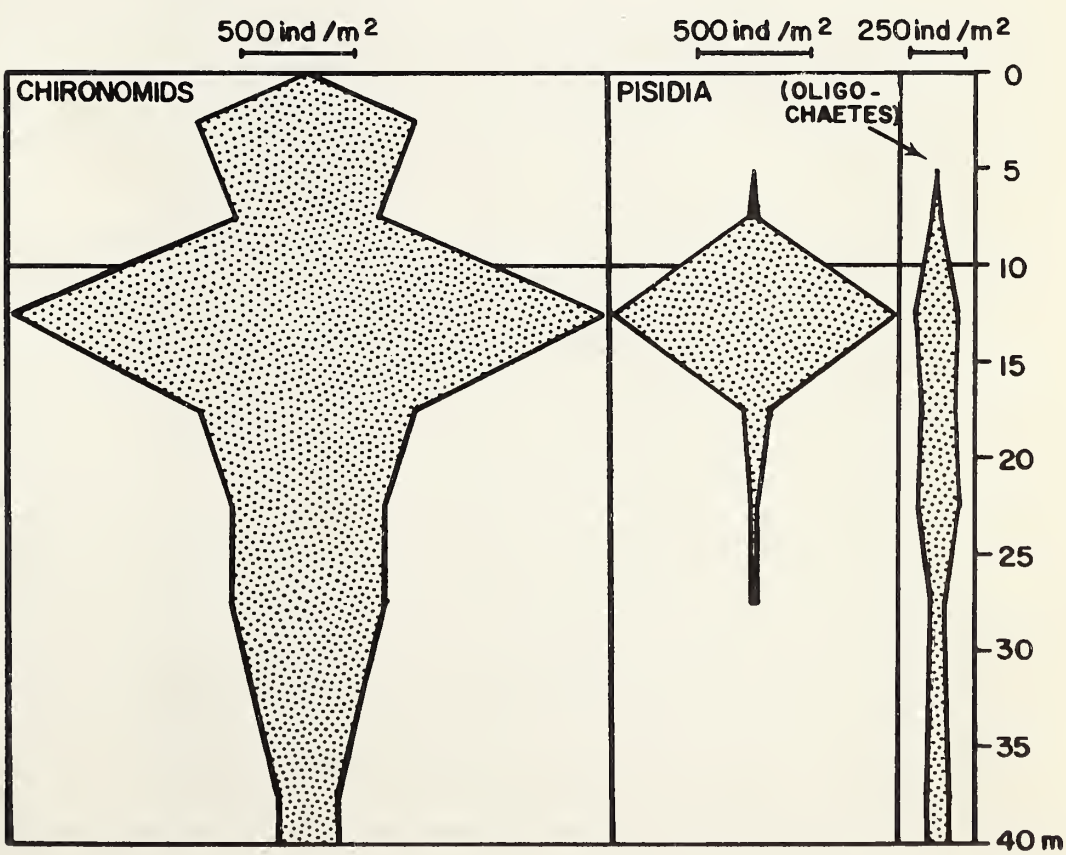
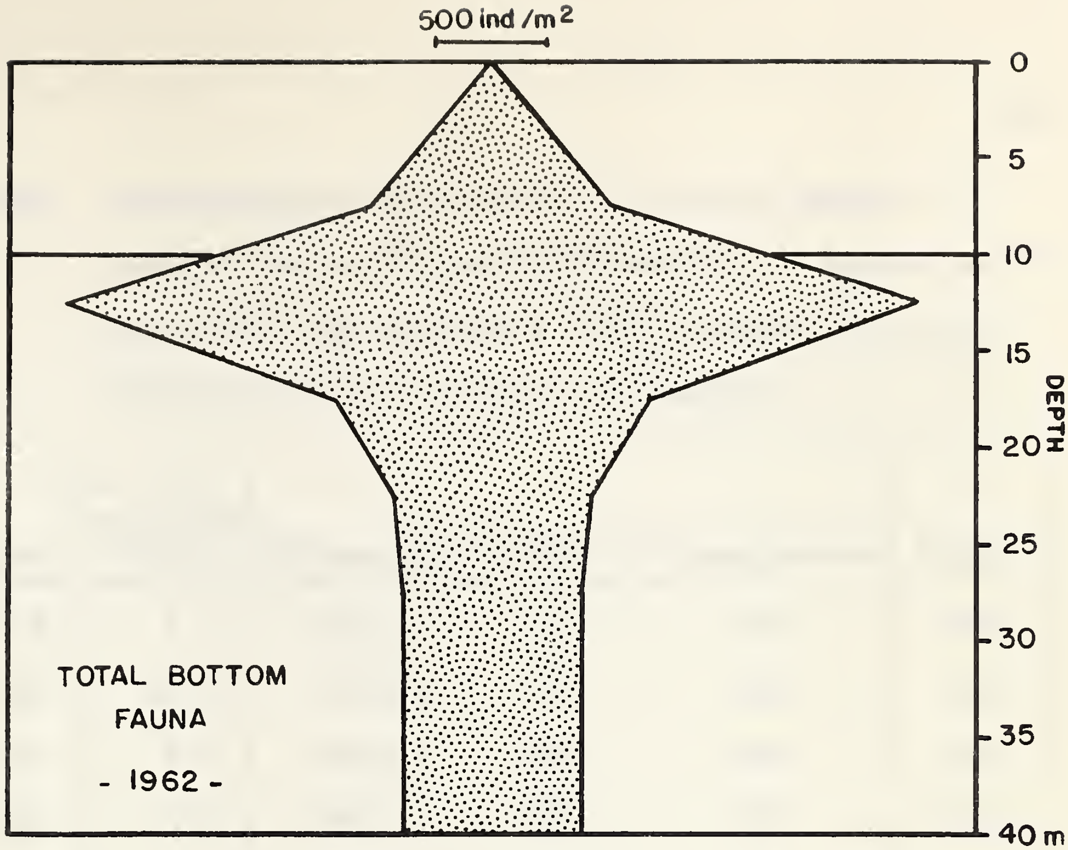

500 ind/m2
500 ind/m2
250 ind/m2
CHIRONOMIDS
PISIDIA
(OLIGO-
CHAETES)
0
5
10
15
20
25
30
35
40 m

FIG. 26. Bathymetrical distribution of the total bottom fauna and its components for Barrier Reservoir, 1962.


500 ind /m2
0
5
10
15
20
25
30
35
40 m
DEPTH
TOTAL BOTTOM
FAUNA
- 1962 -

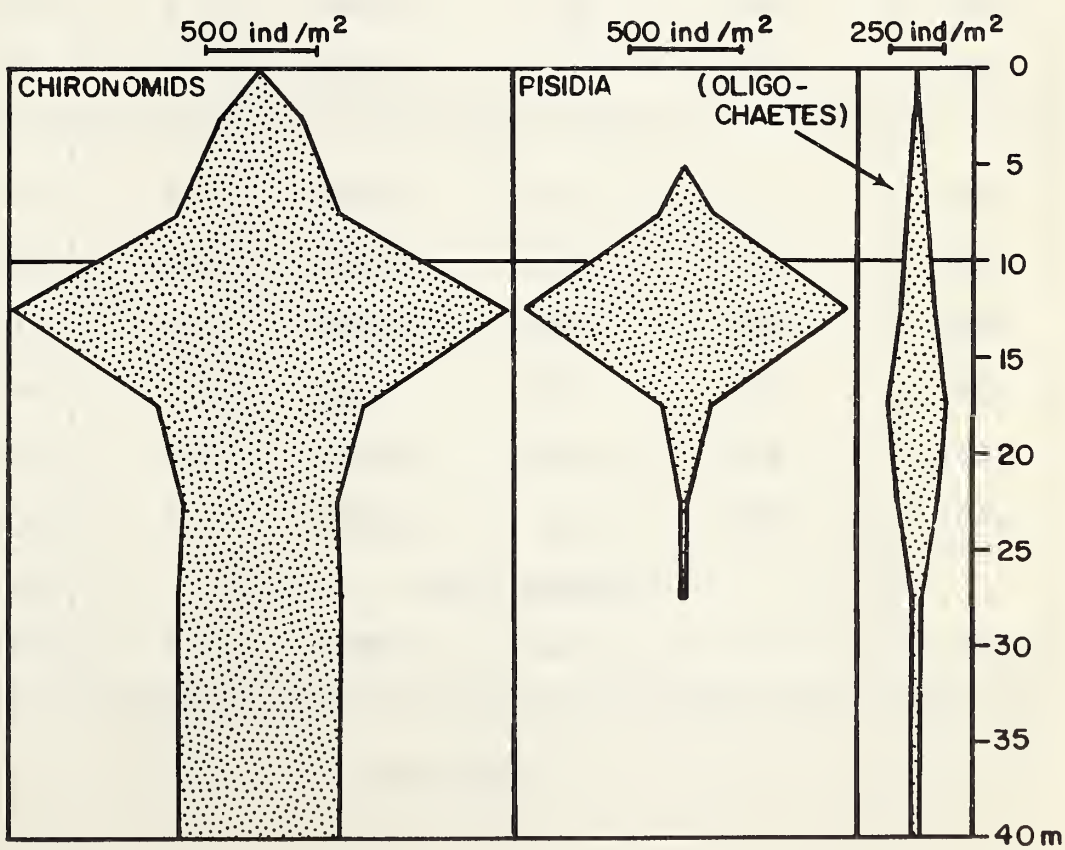

500 ind /m2
500 ind /m2
250 ind /m2
CHIRONOMIDS
PISIDIA
(OLIGO-
CHAETES)
0
5
10
15
20
25
30
35
40 m

Table XII. Bathymetrical distribution of major groups of benthic fauna in Barrier Reservoir. Values given, obtained from averaging total samples for given depth zone and are given as No./m^2.

	Depth (m.)	No. of Dredging Stns.	Chironomids	Pisidia	Oligochaetes	Total
	0 - 5	4	1073	--	69	1142
	5.5 - 10	12	655	47	103	805
1	10.5 - 15	8	2418	1052	509	3979
9	15.5 - 20	6	1401	254	349	2004
6	20.5 - 25	4	1362	13	371	1846
0	25.5 - 30	4	2151	4	276	2431
	30.5 - 35	2	1858	30	556	2444
	35.5 - 40	1	1155	--	698	1853
	0 - 5	7	1965	--	--	1965
	5.5 - 10	11	1315	60	56	1431
1	10.5 - 15	6	5284	2530	388	8202
9	15.5 - 20	6	1957	237	310	2504
6	20.5 - 25	6	1384	52	379	1815
1	25.5 - 30	5	1422	52	168	1642
	30.5 - 35			not sampled		
	35.5 - 40	1	595	--	--	595

continued

Table XII. (continued):

	Depth (m.)	No. of Dredging Stns.	Chironomids	Pisidia	Oligochaetes	Total
	0 - 5	7	720	--	2	722
	5.5 - 10	13	1474	483	194	2151
1	10.5 - 15	7	4474	2827	310	7611
9	15.5 - 20	5	1866	444	526	2836
6	20.5 - 25	5	1384	9	392	1785
2	25.5 - 30	6	1465	26	125	1616
	30.5 - 35		not sampled			
	35.5 - 40		not sampled			

pisidia falls markedly in the lower profundal (below 20 m.) being concentrated primarily in a region extending down 10 metres from the drawdown limit. The oligochaetes and the chironomids occur in appreciable numbers in the deeper portions of the lake.

An analysis of the bottom fauna taken from the dredging sites shown in Figure 27 is included in Figure 28. Figure 28 is a diagrammatic profile of Barrier Reservoir drawn from point A to point B as indicated in Figure 27. The drawdown limits and the corner of the lake are indicated. Above the profile of the lake bottom, the numerical abundance

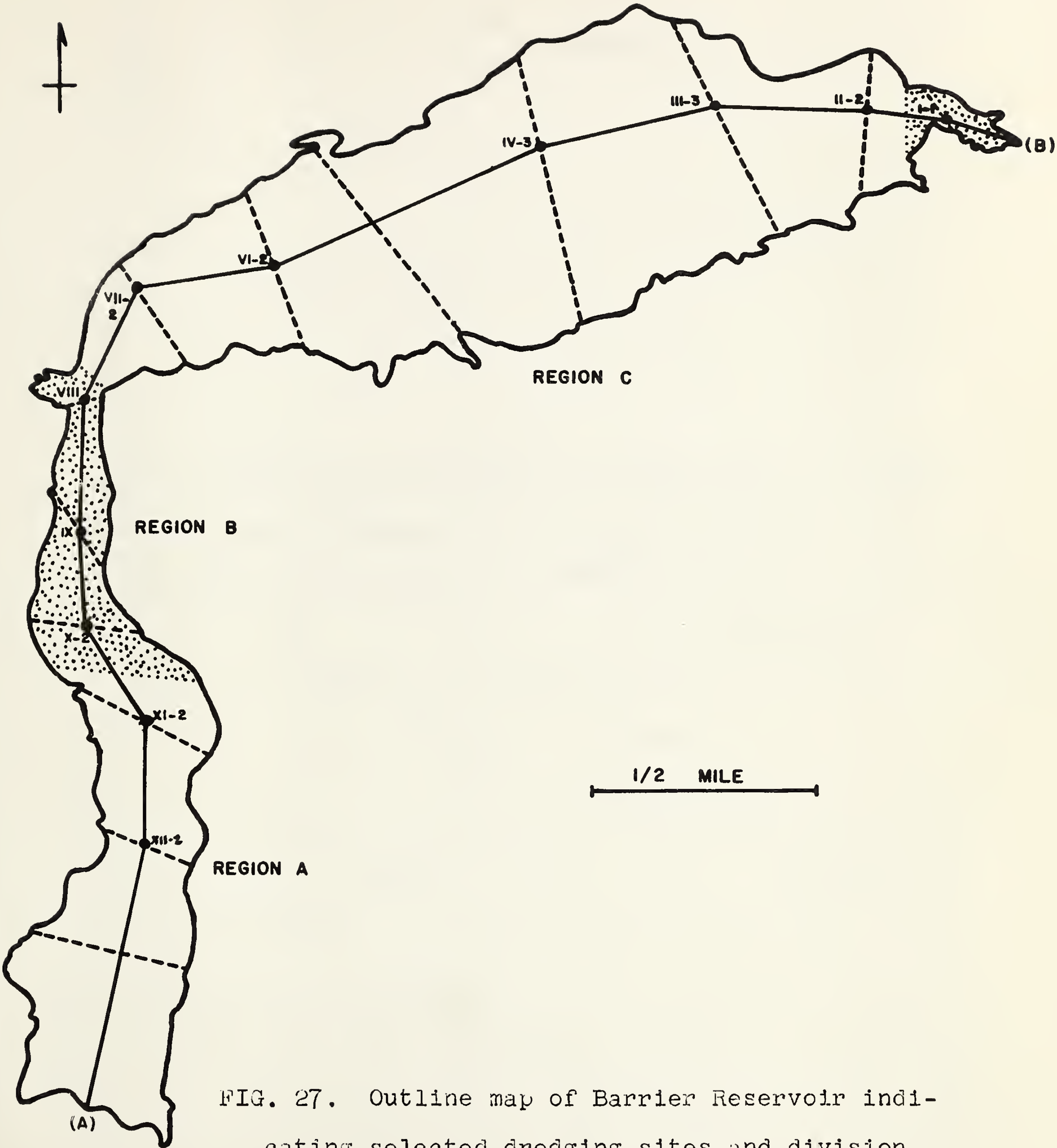
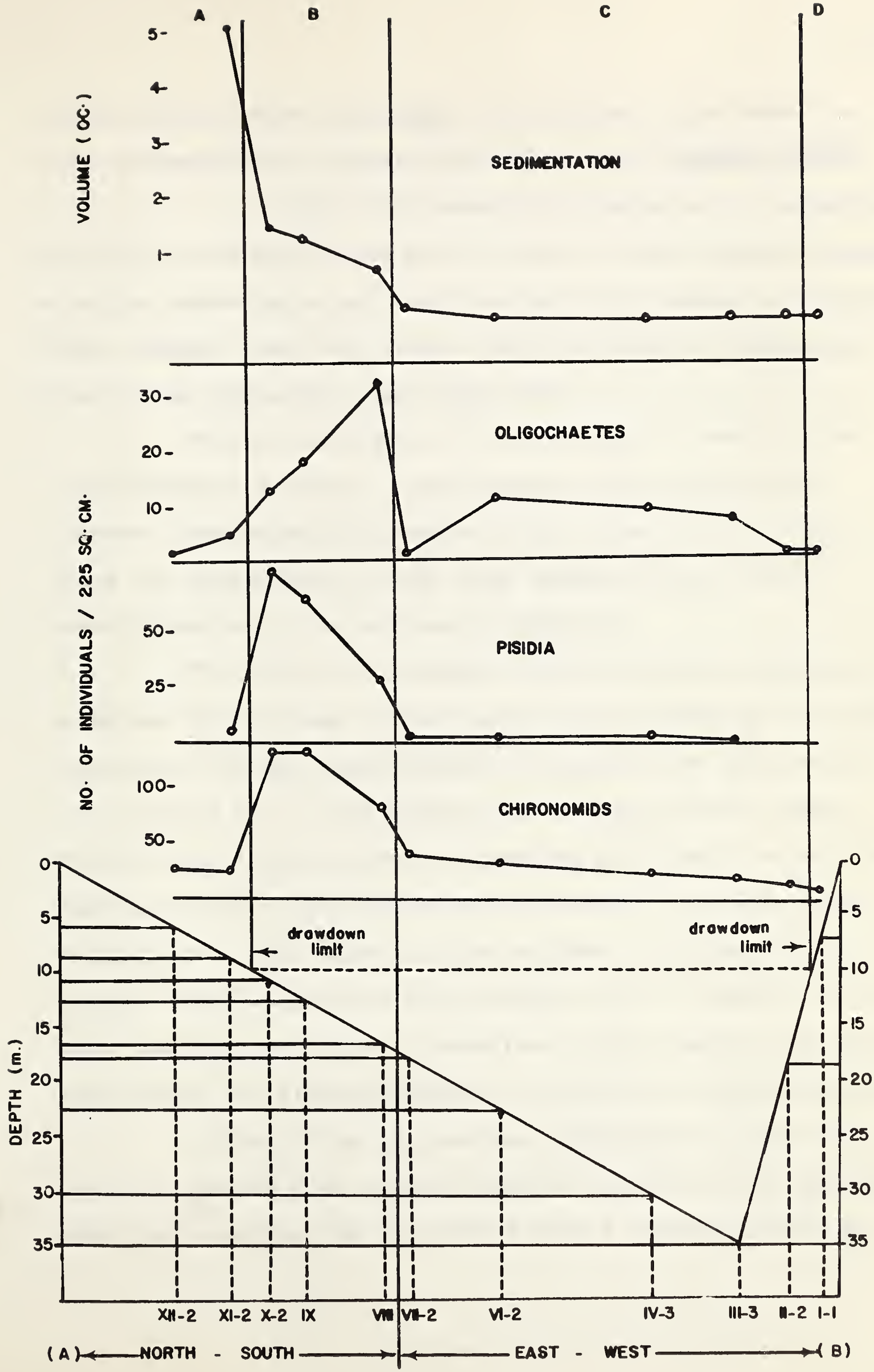
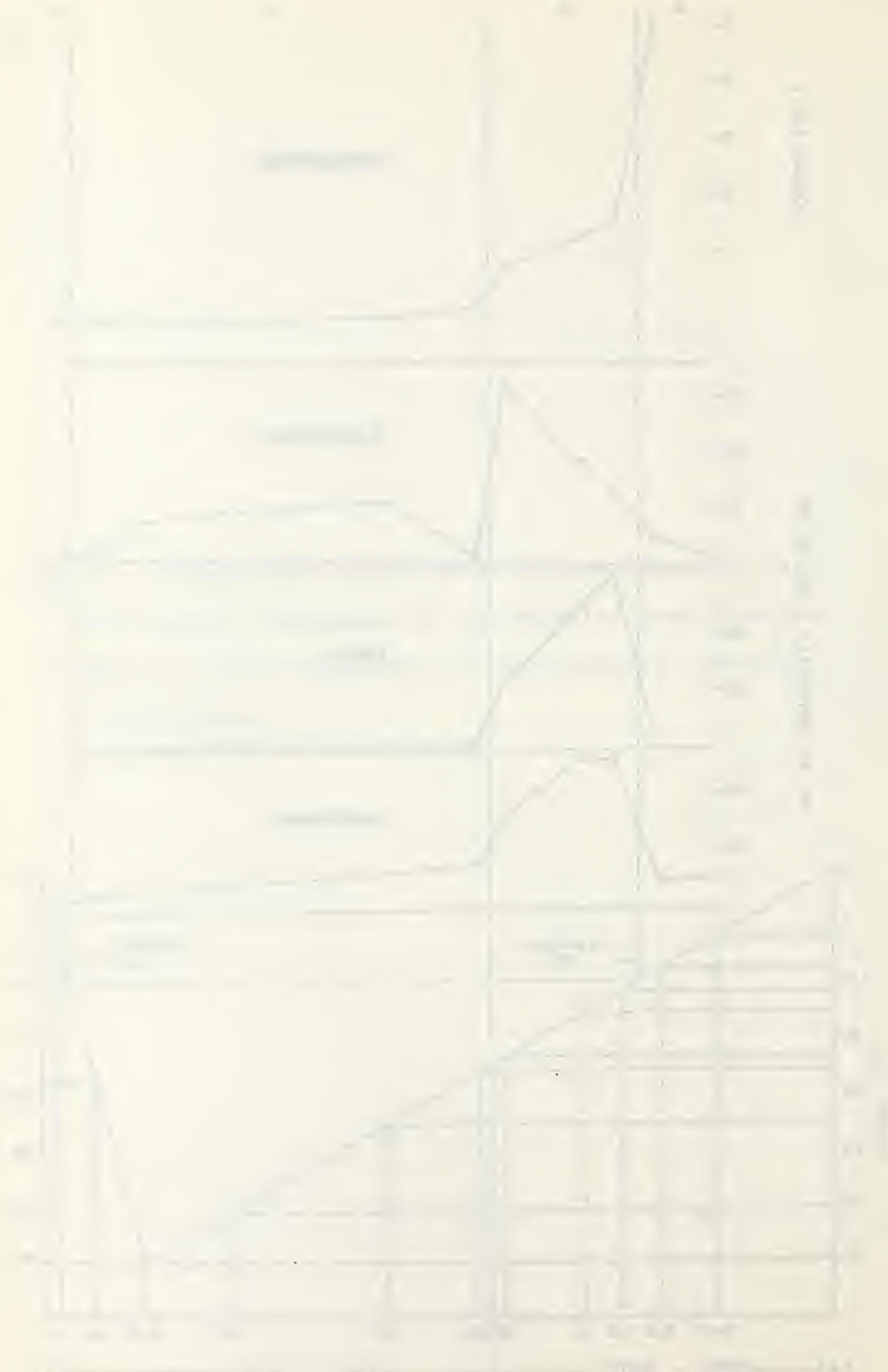


FIG. 27. Outline map of Barrier Reservoir indicating selected dredging sites and division of reservoir into regions.

FIG. 28. Diagrammatic profile of Barrier Reservoir with the numerical abundance of the benthic fauna in relation to factors affecting its distribution, including sedimentation.



A
B
C
D
VOLUME (CC.)
SEDIMENTATION
OLIGOCHAETES
PISIDIA
CHIRONOMIDS
NO. OF INDIVIDUALS / 225 SQ. CM.
DEPTH (m.)
drawdown limit
drawdown limit
XII-2
XI-2
X-2
IX
VIII
VII-2
VI-2
IV-3
III-3
II-2
I-I
(A) NORTH - SOUTH
EAST - WEST (B)



of the major bottom components are included; also shown are some sedimentation figures obtained in 1961 (Nursall, 1961).

Table XIII summarizes the data. A comparison of the percentages of the major groups in this selected sample with the percentages derived from the total number of dredgings would suggest that this series could be taken as representative of the whole lake (see Table XV).

Maximal abundance for all groups is noted in the region between transect X and transect VIII, the latter transect indicating the region of the corner of the lake, where the orientation of the lake changes from a north-south direction to an east-west direction.

The effect of drawdown in limiting the numbers of organisms in the zone of fluctuation can be seen by comparing the values for the three groups in passing from station XI-2 to station X - 2; the difference in depth between these two stations is two metres, suggesting that depth is not the important factor in differences of abundance between these two regions. This effect is not evident in an examination of the values in passing from station II-2 to station I-1 as other influencing factors operative in this region come into play; these are discussed below in relation to sedimentation.

A sharp drop in numerical abundance is also indicated in passing from station VIII to station VII-2; between these two stations the lake turns from a north-south to an

Table XIII. Average numerical abundance of chironomids, pisidia and oligochaetes for selected stations in Barrier Reservoir. (Values for 225 sq. cm. of bottom.)

		XII-2	XI-2	X-2	IX	VIII	VII-2	VI-2	IV-3	III-3	II-2	I-I
CHIRONOMIDS	1960	22.8	13.1	74.0	74.0	67.8	35.8	36.4	22.2	26.8	20.3	9.6
	1961	36.3	36.2	148.0	175.1	94.0	56.4	40.7	26.8	13.8	19.6	17.4
	1962	27.8	28.7	177.1	161.8	103.0	46.1	33.5	38.4	23.5	17.0	12.2
	MEAN	28.9	26.0	133.0	133.6	84.9	46.1	36.8	29.1	21.3	18.9	13.0
PISIDIA	1960	-	9.5	55.8	38.8	28.8	1.6	0.5	0.1	1.0	-	-
	1961	-	0.5	64.5	76.4	24.5	0.4	-	3.8	-	-	-
	1962	-	3.4	116.7	76.2	31.7	0.3	0.5	1.4	-	-	-
	MEAN	-	4.4	79.0	63.8	28.3	0.7	0.3	1.7	0.3	-	-
OLIGOCHAETES	1960	4.2	5.1	19.8	22.3	23.6	1.8	8.5	10.5	16.2	0.3	-
	1961	-	2.9	7.5	15.0	31.7	1.1	15.8	12.6	5.0	-	-
	1962	0.1	4.5	10.1	15.8	43.7	0.5	8.8	3.9	1.6	0.2	0.3
	MEAN	1.4	4.1	12.4	17.7	33.0	1.1	11.0	9.0	7.6	0.1	0.1

NOTE: During 1962, stations XII-2 and XI-2 were replaced by stations M-9 and M-5 respectively.

east-west direction. One of the factors contributing to this marked reduction in numbers is the relative amounts of allochthonous material available to these two regions upon entering the lake via the Kananaskis River. This is portrayed graphically in Figure 28. Sedimentation values (as indices of allochthonous materials) are minimal at the easternmost portion of the lake and this factor is likely correlated to the reduced abundance of bottom fauna of this region; the small amount of bottom fauna would tend to mask the effect of fluctuation of water levels in this portion of the lake.

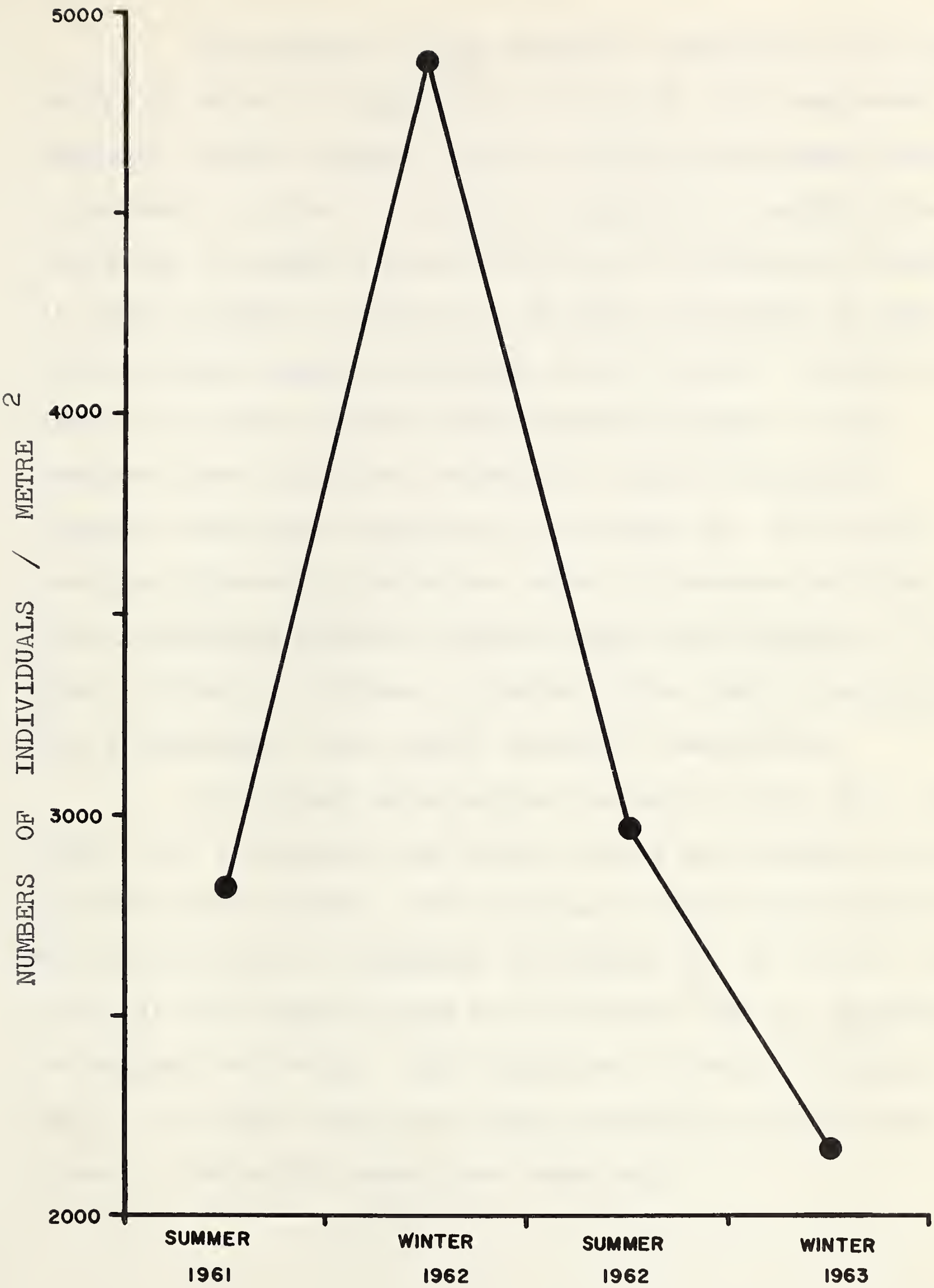
Table XIV summarizes the percentage abundance of the three groups of benthic organisms for the regions indicated in Figures 27 and 28. Region A - lying between inlet end and low water level, exposed for several weeks in spring; Region B - lying in north-south arm between low water mark and corner of reservoir, always under water; Region C - lying in east-west arm, from corner to low water mark at east end, always under water and including deepest part of lake. Region B accounts for 73.8% of the total fauna of the stations included and represents the region of optimal conditions for the majority of organisms present in the benthos of Barrier Reservoir.

Figure 29 indicates the annual variation in numerical abundance for the years 1961 to 1963 in Barrier Reservoir.

Table XIV. Numerical distribution of chironomids, pisidia, and oligochaetes in Barrier Reservoir, from selected stations. These stations are grouped into regions A, B, and C. Values are the average numbers for a sample with an area of 225 sq. cms.

		A XII-2 XI-2	B X-2 IX VIII	C II-2 III-3 VII-2 VI-2 IV-3	TOTAL NOS.	%
Chironomids	Nos.	27.5	117.1	30.4	175.0	66.2
	%	15.7	66.9	17.4		
Pisidia	Nos.	2.2	57.0	0.6	59.8	22.6
	%	3.6	95.3	0.1		
Oligochaetes	Nos.	2.8	21.0	5.8	29.6	11.2
	%	9.5	70.9	19.6		
Total Numbers		32.5	195.1	36.1	264.4	100.0
%		12.3	73.8	13.9		

FIG. 29. Annual variation in numerical abundance of the total bottom fauna in Barrier Reservoir.

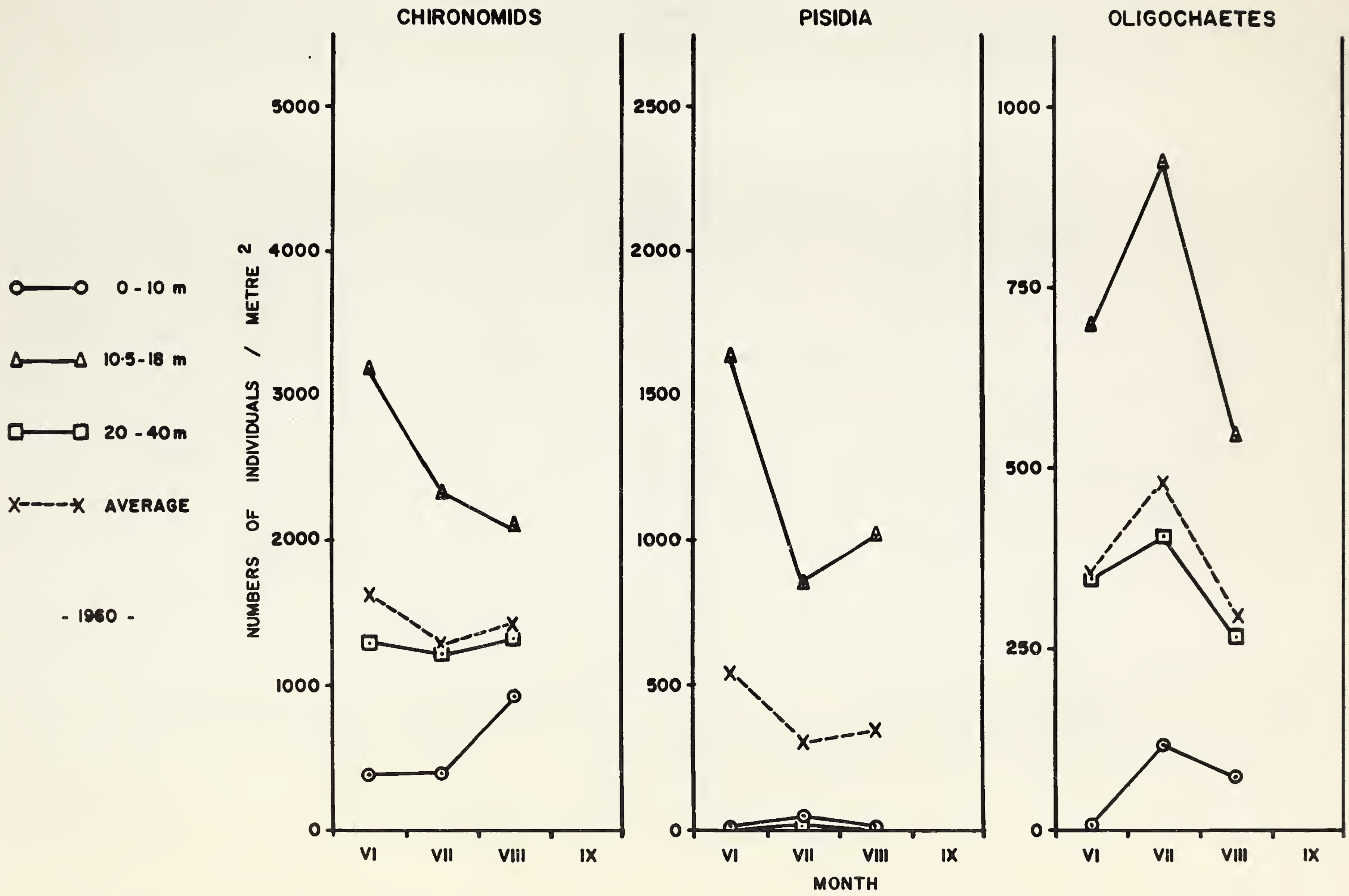


5000
4000
3000
2000
NUMBERS OF INDIVIDUALS / METRE 2
SUMMER 1961
WINTER 1962
SUMMER 1962
WINTER 1963

An analysis of the seasonal variation of the major groups is shown in Figures 30, 31 and 32. No consistent seasonal pattern emerges for the overall chironomid abundance. A tendency for the 0 - 10 metre component to exhibit wide variation in numbers occurs and this is especially evident in 1961 and 1962. The 10.5 - 18 metre component is less affected with seasonal changes, while the 20 - 40 metre component is least affected with seasonal changes. The combined data collected during the study are grouped together and shown graphically in Figure 33. The total average chironomid population shows a midsummer minimum with increasing numbers towards August and September. The pisidia tend to increase in numbers from June to September; the oligochaetes show little seasonal fluctuation.

All groups have maximal numbers in the 10.5 - 18 metre zone throughout the summer months and probably throughout the entire season. The dominance of the chironomids at all depth zones is indicated in Figures 30, 31 and 32, derived from all the samples taken in the months June to September throughout the study. This dominance is most striking in the 0 - 10 metre zone, the region directly subject to exposure. Table XVI summarizes these data.

FIG. 30. Seasonal variation in numerical abundance of the major groups of bottom fauna for Barrier Reservoir, 1960.



CHIRONOMIDS
PISIDIA
OLIGOCHAETES
0 - 10 m
10·5 - 18 m
20 - 40 m
AVERAGE
- 1960 -
NUMBERS OF INDIVIDUALS / METRE 2
5000
4000
3000
2000
1000
0
2500
2000
1500
1000
500
0
1000
750
500
250
0
VI
VII
VIII
IX
MONTH

FIG. 31. Seasonal variation in numerical abundance of the major groups of bottom fauna for Barrier Reservoir, 1961.

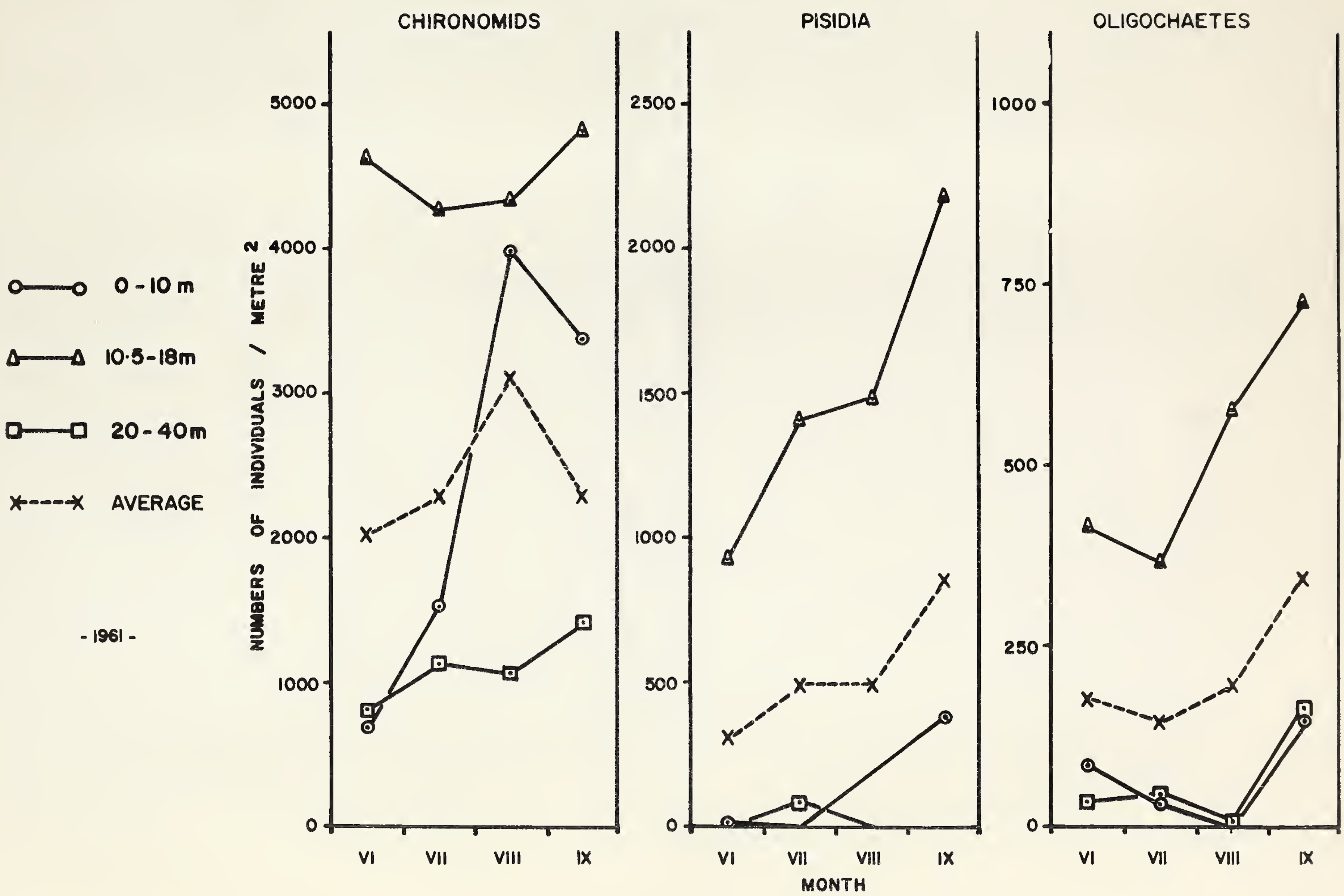

CHIRONOMIDS
PISIDIA
OLIGOCHAETES
NUMBERS OF INDIVIDUALS / METRE 2
0 - 10 m
10·5 - 18m
20 - 40m
AVERAGE
- 1961 -
0
1000
2000
3000
4000
5000
500
1500
2500
250
750
VI
VII
VIII
IX
MONTH

FIG. 32. Seasonal variation in numerical abundance of the major groups of bottom fauna for Barrier Reservoir, 1962.

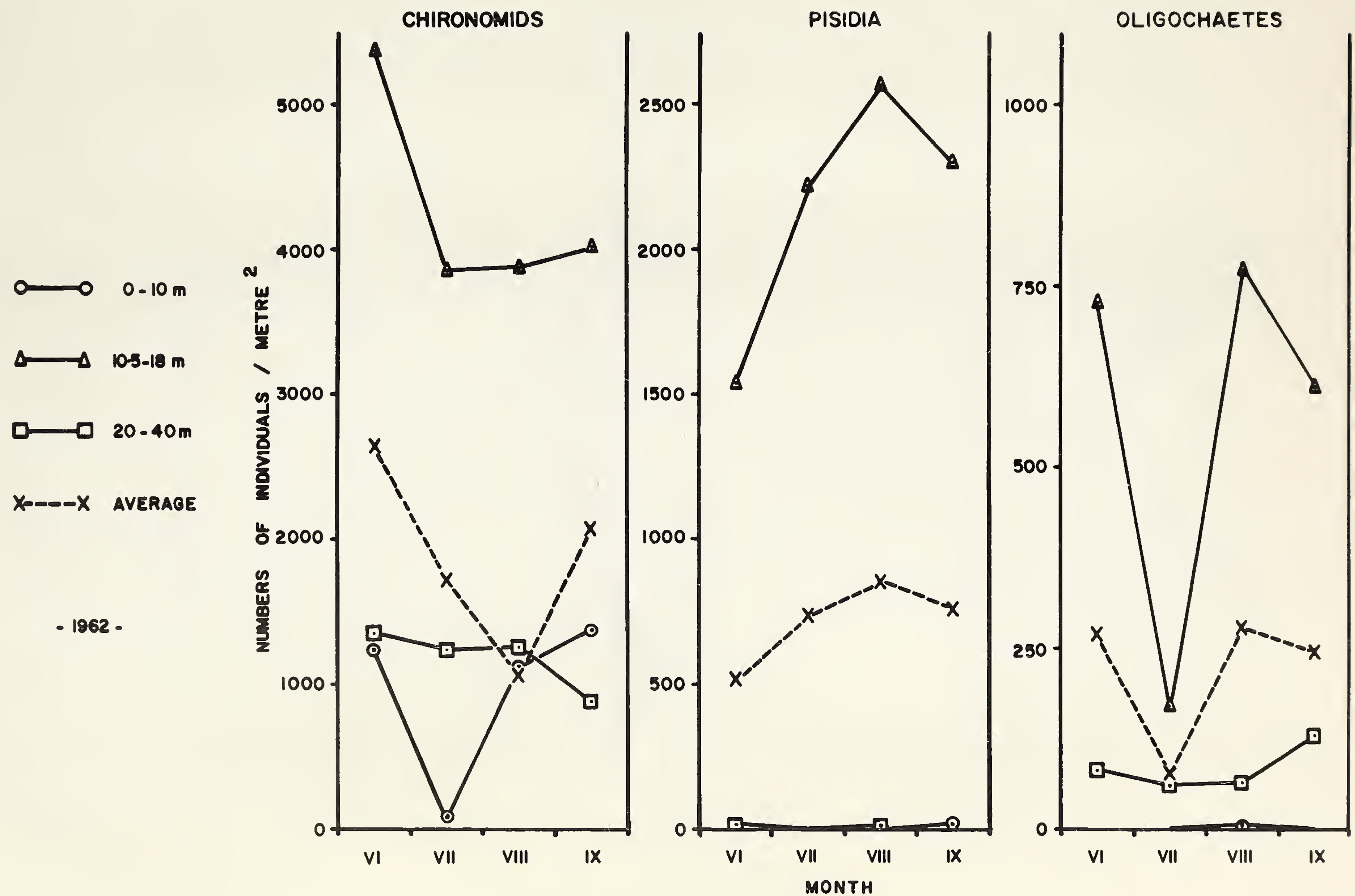
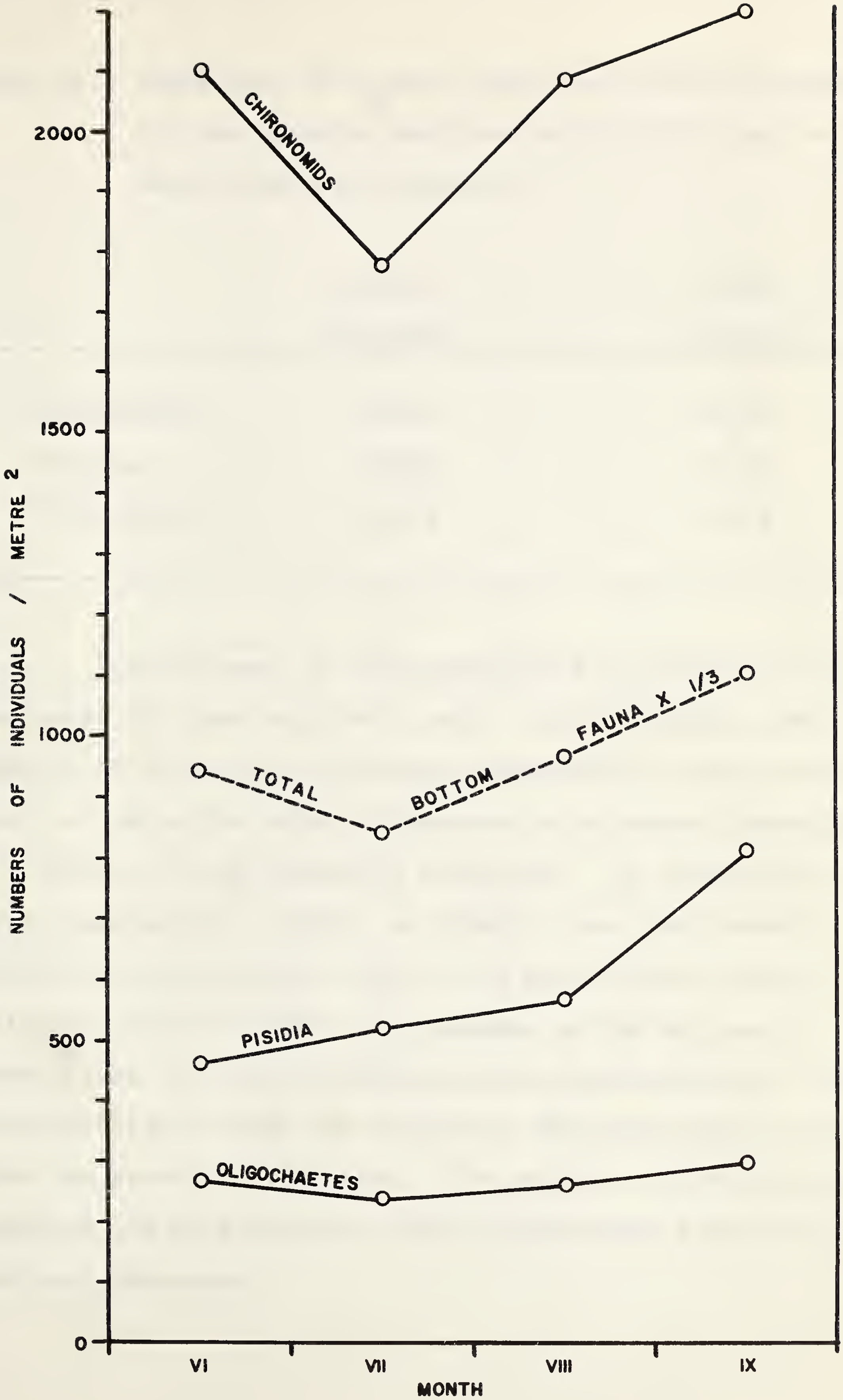

CHIRONOMIDS
PISIDIA
OLIGOCHAETES
0 - 10 m
10.5-18 m
20 - 40 m
AVERAGE
- 1962 -
NUMBERS OF INDIVIDUALS / METRE 2
MONTH
VI
VII
VIII
IX
0
1000
2000
3000
4000
5000
500
1500
2500
250
750

FIG. 33. Seasonal variation in numerical abundance of the benthic groups averaged from data obtained during 1960, 1961 and 1962, in Barrier Reservoir.



2000
1500
1000
500
0
NUMBERS OF INDIVIDUALS / METRE 2
CHIRONOMIDS
TOTAL BOTTOM FAUNA X 1/3
PISIDIA
OLIGOCHAETES
VI
VII
VIII
IX
MONTH

Table XV. Comparison of balance among the benthic components for the selected stations and for all stations used in Barrier Reservoir.

	Selected Stations	Total Stations
Chironomids	66.2%	67.4%
Pisidia	22.6%	21.2%
Oligochaetes	11.2%	11.4%

Percentages of this magnitude for chironomids have been noted in other regulated lakes. Grimås (1961) gives a value of 31.9% for the chironomid component of Lake Blåsjön prior to regulation with an increase in chironomid abundance to a value of 54.1% following regulation. An unregulated lake, Ankarvattnet, similar to Blåsjön, has a chironomid population representing 32.2% of the entire bottom fauna. Similarly, Rawson (1958) cites changes in the balance of bottom fauna for Lake Minnewanka following regulation. The chironomid fauna which was originally 52% increased to 93% after ten years of regulation. The molluscs which originally comprised 39% were reduced to 5%; oligochaetes and gastropods also decreased.

Table XVI. Seasonal variation in the numerical abundance of the major benthic forms in Barrier Reservoir. (Values for m^2).

		June	July	August	September
1960	Chironomids	1620	1295	1432	
	Pisidia	546	306	343	
	Oligochaetes	354	482	294	
1961	Chironomids	2044	2302	3110	2302
	Pisidia	314	497	494	852
	Oligochaetes	178	146	195	345
1962	Chironomids	2640	1733	1074	2094
	Pisidia	520	741	857	767
	Oligochaetes	270	77	280	247
AVERAGE	Chironomids	2101	1777	2082	2198
	Pisidia	460	515	565	809
	Oligochaetes	267	235	256	296
AVERAGE TOTAL FAUNA		2828	2527	2903	3303

B. Littoral Habitats of Barrier Reservoir.

The springtime use of the stored water of Barrier Reservoir results in exposure of much of the shallower region of the reservoir. Figure 34 is an outline map of the reservior showing the extent of drawdown. Up to 37% of the total bottom area of the lake becomes exposed; this figure was arrived at from data given by Nursall (1952) which gives the area of the 0 to 10 metre zone as 37%; the value calculated from Figure 34 was 34%. Figures 35 and 36 show the major portion of the reservoir which is affected by drawdown. A series of sampling stations were set up in the exposed areas and samples of mud taken before and after the water level reached f.s.l. An examination was made in the rocky areas bordering the regions of mud as well as investigations of the undersides of logs and roots lying on the lake bottom.

Depending on the depth of the region, the time of exposure varied from 50 days (for 10.5 m.) to 84 days (for 2 m.). Various bottom organisms were observed to tolerate these conditions of exposure. The rocky shore regions were found to harbour large terrestrial oligochaetes (Family Lumbricidae) and crane-fly larvae (*Tipula*). Although the tipulids are sparsely represented in dredging samples they occur commonly along the rocky shores of the reservoir.

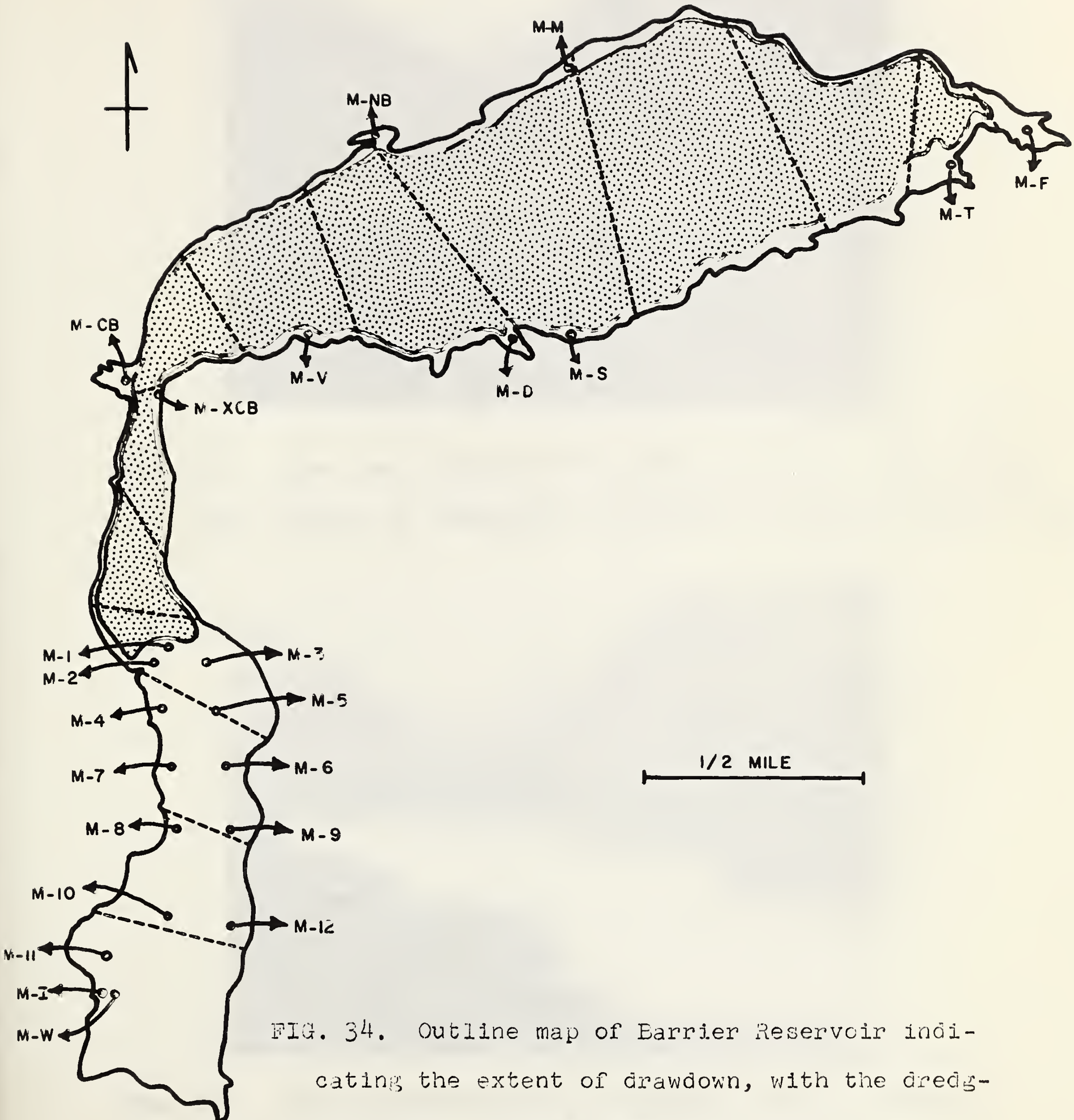


FIG. 34. Outline map of Barrier Reservoir indicating the extent of drawdown, with the dredging sites of the exposed region shown.
(stippled portion is the surface area at l.w.l.)

Fig. 35. Inlet end of Barrier Reservoir at l.w.l. Ice patches still remain on southernmost portion of reservoir (May, 1962).

Fig. 36. Inlet end of Barrier Reservoir at f.s.l. (August, 1962).

Objects such as logs and roots, partly buried in the sand and mud, sheltered many chironomids and miscellaneous other organisms (eg. Megaloptera, Plecoptera, and Oligochaeta). Piles of driftwood which are concentrated mainly in the easternmost portion of the lake provided suitable cover for many organisms. Mats of Chara and mosses contained numerous chironomids as well as other forms; these situations probably retained moisture more effectively than the exposed mud itself.

Other organisms maintained local distributions throughout the exposed regions. Numerous caddis fly cases with occasional inhabitants were found at station M-V; these were larvae of the Genus Limnephilus. Alderfly larvae of the Genus Sialis were found at the inlet end of the lake; stoneflies of the Family Perlodidae also occurred at the inlet end of the lake.

Figure 37 shows numerical changes in abundance of chironomids due to exposure, for selected stations.

Activity of the organisms was evident to a varying degree depending on the moisture content of the mud. In very moist situations such as near the edge of the low water level or near the edges and in the mud of isolated pools, a labyrinth of 'trails' and 'tracks' with an occasional chironomid or clam could be seen (see Figure 38); in moist but higher regions, there was an absence of 'trails' and 'tracks', but openings to the surface were apparent; in the hard-packed drier regions, no surface indications were

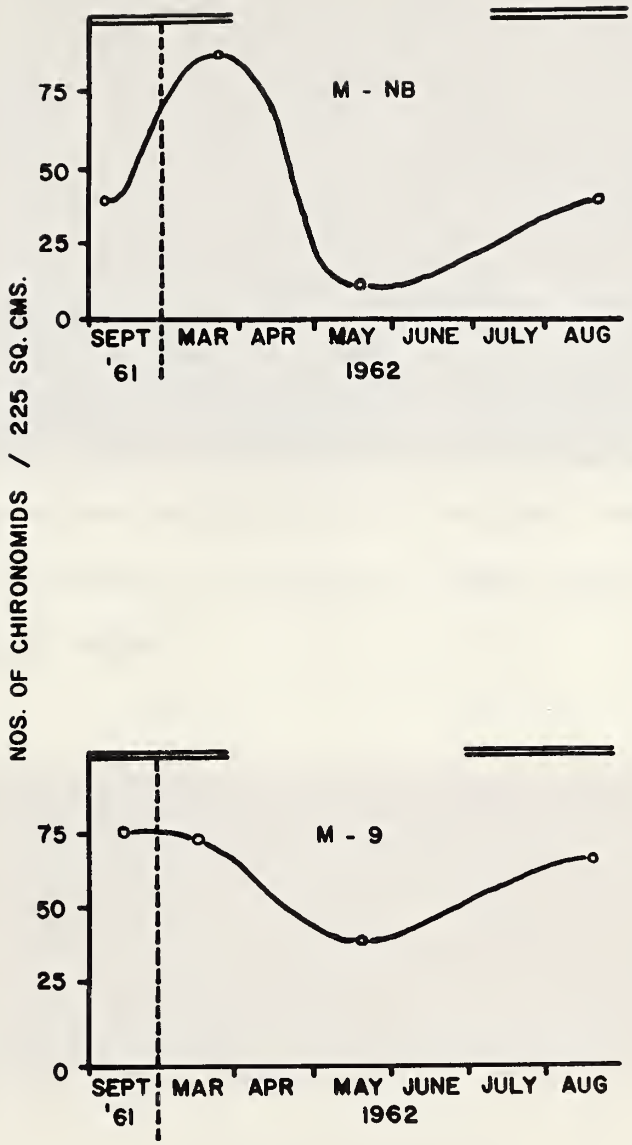


FIG. 37. Numerical abundance of chironomids in relation to water level fluctuation. Duration of water cover indicated by double line at top of graphs. The stations used are M-NB and M-9.

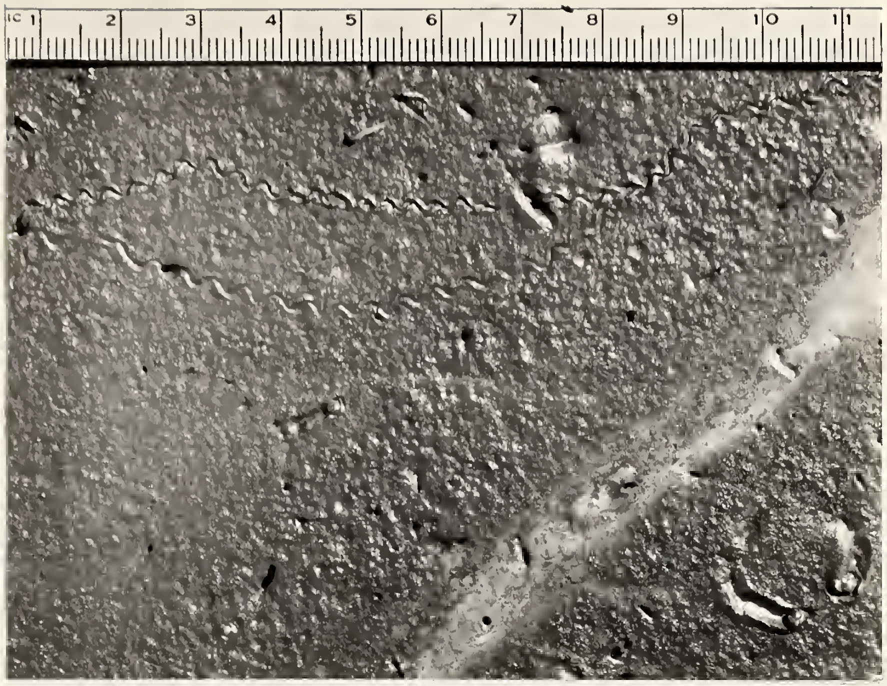


Fig. 38. Surface indications of various organisms in moist, exposed bottom. Pisidia in lower right corner. 'Trails' parallel ruler.

Fig. 39. Hard-packed and relatively dry bottom. Chironomids and single white dipterous larva taken below surface of this mud.

evident (see Fig. 39). In these drier regions only the chironomids occurred in large numbers. Organisms could be found active above the mud surface in areas overlain by algal mats and mosses (see Fig. 40).

A total of 30 samples were taken of the exposed regions. Table XVII indicates the duration of exposure and composition of the chironomid fauna present. Tendipes sp. and Tanytarsus sp. are the dominant forms with Tendipes sp. able to tolerate the extended conditons of exposure best as indicated by its abundance, especially after 70 days of exposure; at this time it accounts for 83% of the chironomids present. It is noted that both Tendipes sp. and Tanytarsus sp. are large forms, and this factor may account for their ability to withstand the process of desiccation more effectively than the smaller forms.

The shore types discussed earlier provided varying degrees of suitability for benthic forms (cf. Fig. 4). Regions of clay or a mixture of sand and clay provided the most suitable habitats for bottom organisms; this situation was further enhanced when mats of Chara or mosses occurred on the clay. (cf. Figs. 4, 41 and 42). Chironomids were found in steep regions consisting primarily of sand as in Figure 11. Areas consisting of hard-packed clay overlain by gravel contained very few organisms (Fig. 12). The steep, rocky regions, especially along the western shore of the reservoir appeared devoid of organisms (Figs. 5 and 6) as did the

Table XVII. Chironomid species inhabiting the exposed region of Barrier Reservoir, 1962. (Numbers for sample of 225 sq. cm. in area.) Values obtained by totalling the number of individuals at a given period of exposure, and dividing this total by the number of samples taken for that period. (Values to the nearest whole number.)

Species	Days of Exposure																	
	55	57	59	61	63	65	67	69	71	%	73	75	77	79	81	83	85	%
<u>Tendipes</u> sp.	13	28	51	14	1		8	71		43.7	48			66		16	30	83.3
<u>Tendipes</u> nr. <u>riparius</u>	2	3	6		2	2	14			6.8				4			18	11.5
<u>Tanytarsus</u> sp.	45	13			8	74	18			37.1				4			1	2.6
<u>Calospectra</u> nr. confusa	10							1		2.6								
<u>Stempellinella</u> nr. <u>brevis</u>	1			1			3			1.2				1				0.5
<u>Procladius</u> nr. <u>culiciformis</u>	9	6			1		2	6		5.6				2			1	1.6
<u>Tanytarsus</u> nr. <u>nigricans</u>						4		6		2.3								
<u>Prodiamesa</u> sp.							2			0.5								
Others							1*			0.3				1**				0.5

* <u>Cryptochironomus</u> nr. <u>fulvus</u>
** <u>Trichocladius</u> sp.

Fig. 40. Organisms found on surface of exposed bottom, underneath algal mat. Large organism is a tipulid larva, others are chironomid larvae.

Fig. 41. Looking southwest to inlet end of Barrier. Moist exposed clay in foreground, with drier shore regions in background. (June, 1962.)

Fig. 42. From southwest shore at inlet end of Barrier. Extensive developments of mats of Chara and algae, which appear as light patches. (June, 1962.)

portion of the shore comprising the dam; this latter region consists of large rocks and boulders and lacks clay or sand (Fig. 13). Areas consisting of bedrock exposures were devoid of organisms except for the portions with some clay overlying the bedrock (cf. Figs. 7 and 8).

C. The Chironomid Fauna of Barrier Reservoir.

i. General

A comparison of the classification of the various groups of chironomids during former studies and with that used at present, is given below. To facilitate comparisons with other workers, the older classification and terminology is used in this study except for the generic and specific names which follow the present classification. The more recent classification referred to, is that given by Roback (1957).

Former classification		Present classification		Species of this study
TANYPODINAE	....	PELOPIINAE	*1.	Pentaneura (melanops gp.) sp.
			*2.	Procladius nr. culiciformis (L.)
ORTHOCLADIINAE	....	HYDROBAENINAE	*3.	Psectrocladius sp. 1
			*4.	Psectrocladius sp. 2
			*5.	Trichocladius sp. ?

DIAMESINAE .... DIAMESINAE	*6.	_Prodiamesa_ (_Monodiamesa_) sp.
	7.	_Prodiamesa_ nr. _olivacea_ (Meig.)
	*8.	_Diamesa_ nr. _nivoriunda_ (Fitch)
	*9.	Diamesinae sp.
CHIRONOMINAE = TENDIPEDINAE		
CHIRONOMINI .... TENDIPEDINI	10.	_Odontomesa_ nr. _fulva_ (Kieff.)
	*11.	_Tendipes_ (_T._) _attenuatus_ (Walk.) [= _decorus_ Joh.]
	*12.	_Tendipes_ (_T._) nr. _riparius_ (Meig.)
	*13.	_Tendipes_ sp. ?
	14.	_Polypedilum_ (_fallax_ gp.)
	*15.	_Harnischia_ nr. _pseudotener_ (Goetgh.)
	*16.	_Harnischia_ nr. _nais_ Townes
	*17.	_Cryptochironomus_ nr. _fulvus_ (Joh.)
	*18.	_Tanytarsus_ nr. _nigricans_ (Joh.)
	*19.	_Tanytarsus_ (_Tribelos_) sp.

TANYTARSINI .... CALOPSECTRINI*20. Stempellinella nr. brevis (Edw.)

*21. Calopsectra nr. confusa (Mall.)

* Identified by S. Roback.

The genus Tanytarsus, formerly included within the Tribe Tanytarsini, is now grouped with the Tribe Tendipedini; for comparative purposes, this genus is left in the Tribe Tanytarsini.

ii. Historical

Nursall's investigation of Barrier Reservoir during 1947 to 1949 indicated an initially scanty bottom fauna; the first chironomids taken were larvae of the genus Polypedilum (= Pentapedilum). This form was soon replaced by other members of the Tribe Chironomini. Genera of the Tribe Tanytarsini also appeared at this time (July, 1947). In August to September, 1947, Orthocladiinae appeared, as did representatives of the Tanypodinae and Diamesinae. Members of the Chironomini remained dominant through 1948. In January, 1949, members of the Tanytarsini became the dominant forms. While the Chironomini greatly decreased in numbers (from 77% in the winter of 1948 to 7% in the winter of 1949), the Tanytarsini comprised 79% of the chironomid fauna at this time. During June, 1949, the Tanytarsini, the Chironomini,

and Polypedilum approximated each other in numbers. The overall benthic sequence for the dominant chironomid groups may be indicated as

Polypedilum .. Chironomus ... Tanytarsus

Nursall gave the following explanation for this succession of dominant forms: Polypedilum was briefly dominant owing to the fact that it was the first chironomid established in the reservoir. Chironomus, a eutrophy-typical form took advantage of the eutrophic conditions resulting from the presence of leaf litter caused by removal of trees and shrubs from the area prior to impoundment. It was suggested that the decaying leaf litter provided suitable food material for Chironomus types. A heavy spring run-off in 1948 completely buried the leaf litter resulting in more oligotrophic conditions, hence the oligotrophy-typical Tanytarsus forms became dominant.

iii. Present Study

The present study is, in part, an attempt to ascertain any changes in the benthic structure since the initial investigation by Nursall.

A total of 21 species have been identified from Barrier Reservoir. Table XVIII indicates the composition of the chironomids according to major groups. The Diamesinae consisting of five species (poorly represented numerically)

Table XVIII. Composition of the chironomid fauna of Barrier Reservoir according to groups.

	No. of species	%
Tanypodinae	2	10
Orthocladiinae	3	14
Diamesinae	5	24
Chironomini	7	33
Tanytarsini	4	19
TOTALS	21	100

are not considered as a major group in subsequent analysis.

The main groups of Chironomidae of Barrier Reservoir are compared with those in several Swedish lakes in Table XIX. An unexpected proportion of the chironomids is made up of the Tribe Chironomini in Barrier Reservoir. It is generally accepted that with increasing altitude and decreasing eutrophy-typical conditions, that the Tanytarsini and Orthocladiinae tend to predominate. Brundin (1958) offers the following bottom faunistical lake type system for Northern Europe:

I   *Heterotrissocladius subpilosus* lakes (ultra-oligotrophic)

I/II   *Tanytarsus* - *Heterotrissocladius* lakes

II   *Tanytarsus lugens* lakes (moderately oligotrophic)

II/III   *Stictochironomus* - *Sergentia* lakes (mesotrophic)

III   *Chironomus* lakes (eutrophic)

- a) *Chironomus anthracinus* lakes (moderately eutrophic)
- b) *Chironomus plumosus* lakes (stronger eutrophic)

The Orthocladiinae larvae play an important part in the ultra-oligotrophic lakes and are strongly dominant in

Table XIX. % Balance between the major groups of chironomids in several subarctic lakes in Sweden, and in Barrier Reservoir. Percentages based on number of species for a given group.

	Blåsjön after reg.	Semming-sjön	Lebbik-vatt-net	Ankar-vatt-net	Blåsjön before reg.	Barrier
Tanypodinae	11	14	12	12	19	12
Orthocladiinae	52	48	39	45	36	19
Chironomini	4	17	22	23	24	44
Tanytarsini	33	21	27	20	21	25
No. of species	27	42	51	56	85	21
Metres above sea-level	435	689	468	448	433	1375

the whole profundal region. The abundance of the profundal fauna is about 300 - 400 individuals per metre^2 (ind. per m^2). Brundin postulates that Heterotrissocladius lakes have a holarctic distribution.

The moderately oligotrophic Tanytarsus lugens lakes are influenced by oxygen microstratification as indicated by the haemoglobin-free Orthocladiinae larvae being restricted primarily to the upper profundal. The Orthocladiinae larvae

of Barrier Reservoir are present in the deeper profundal in small numbers perhaps suggesting that oxygen microstratification does become an important factor in limiting their distribution. (see Table XX).

Table XX. The percentages of chironomids in the different depth zones of Barrier Reservoir (based on number of individuals).

Depth m.	0-2	2.5-8	8.5-10	10.5-12	12.5-14	14.5-20	20.5-30	30.5-40	Total
Tanypodinae	2.5	6.2	10.9	20.4	23.1	40.2	12.6	9.1	18.4
Orthocladiinae	4.3	11.5	5.4	3.6	11.2	5.9	3.9	3.2	6.2
Chironomini	60.8	42.1	28.7	10.1	33.5	31.6	77.5	75.3	36.7
Tanytarsini	32.4	40.2	55.0	65.9	32.2	22.3	6.0	12.4	38.7
No. of species	14	20	20	17	13	13	11	8	21

-- Drawdown limit

Brundin also notes that the larger types of larvae tend to occur in the deeper profundal, the size of the larvae being important for their ability to counteract the microstratification of oxygen; he concludes that the larger larvae are able to obtain oxygen from the zone above that exhibiting microstratification to a degree dependent upon their surface area. In Barrier Reservoir it is the larger forms of larvae

which dominate the profundal region (notably *Tendipes* sp. and to a lesser extent, *Procladius* nr. *culiciformis*).

Due to the intensified oxygen microstratification of eutrophic lakes, the members of the *Tanytarsus lugens* community are eliminated, being replaced by the larger *Tendipes* larvae. This situation appears in the deeper profundal of Barrier Reservoir, although this reservoir exhibits the conditions of an oligotrophy-typical lake.

An analysis of the bathymetrical distribution for the major groups of Chironomidae in Barrier Reservoir is given in Table XX.

The region directly affected by regulation (0 - 10 m.) is dominated by the Chironomini and Tanytarsini. Immediately below the drawdown limit, the Tanypodinae (represented almost exclusively by *Procladius* nr. *culiciformis*) increase significantly compared with the percentage abundance above this level. The Tanypodinae rise to dominance in the 14.5 - 20 metre zone and regress in numbers in the deeper profundal. The Chironomini are the dominant forms of the regulated region, especially of the portion affected to the greatest degree, the 0 - 2 metre zone. In the upper profundal the Chironomini assume a lesser portion of the fauna, but again dominate in the deeper profundal.

The Tanytarsini are well represented in the regulated zone and dominate the region immediately above and

immediately below the drawdown limit. In contrast to what has been found in other oligotrophic lakes, the Tanytarsini do not dominate the lower profundal but are replaced by the Chironomini.

The percentages of the main groups of Chironomidae in the various depth zones of Lake Blåsjön shown in Table XXI can be compared with these for Barrier Reservoir, shown in Table XX.

Table XXI. The percentages of chironomids in the different depth zones of Lake Blåsjön (based on hatching results from Grimås, 1961).

	2-4	5-6	7-8	8-10	10-13	13-20	Total
Tanypodinae	-	-	15	8	18	-	11
Orthocladiinae	50	40	45	58	55	50	52
Chironomini	-	10	5	-	-	-	4
Tanytarsini	50	50	35	34	27	50	33
No. of species	4	10	20	12	11	4	27

-- Drawdown limit.

The number of chironomid species found in the different depth zones of Lake Blåsjön and Lake Ankarvattnet are

shown in Table XXII. This indicates an impoverished fauna for Blåsjön as far down as 1 metre above the drawdown limit.

Table XXII. The number of chironomid species for the different depth zones in Lake Blåsjön and Lake Ankarvattnet. (from Grimås, 1961).

Depth Zone m.	0-2	2-4	4-5	5-6	6-7	7-8	8-10	10-13	13-20	20-30	30-70	70-140
Benthos in Blåsjön	3	3	3	12	18	19	17	14	8	2	3	3
Hatching in Ankar-vattnet		44		38				14				

It is noted that the majority of species in Ankarvattnet, which is an unregulated lake, are in the littoral region.

A similar analysis for Barrier Reservoir showing the average number of species in the various depth zones is given in Table XXIII.

The fauna of Barrier Reservoir is qualitatively poor as regards the number of species, the greatest number of species found in a single dredging being ten. The averages included in Table XXIII indicate a maximum of species immediately below the drawdown limit, and a more gradual decrease in numbers entering the profundal.

Table XXIII. Average number of species found in the different depth zones of Barrier Reservoir.

Depth m.	No. of dredgings	No. of species 1960	1961	1962	Average
0 -5	42	3.9	4.8	3.2	4.0
5.5-10	53	3.2	4.5	3.9	3.9
10.5-15	37	5.2	5.2	6.0	5.5
15.5-20	62	4.0	5.2	4.4	4.5
20.5-25	52	3.8	3.8	4.1	3.9
25.5-30	16	2.4	2.2	3.7	2.8
30.5-35	8			3.1	3.1
35.5-40	11	3.2	3.8		3.5

Quantitatively the fauna is moderately abundant with the deeper profundal averaging 875 ind. per m^2 . The region immediately below the drawdown limit has an average abundance of 4058 ind. per m^2.

A substantial increase in numbers has occurred since Nursall's investigation. In January, 1948, the chironomids numbered approximately 360 ind. per m^2 in the deepest profundal, and 3150 ind. per m^2 below the drawdown limit. These figures were the maximum numbers recorded during his investigation, and the summer averages were smaller.

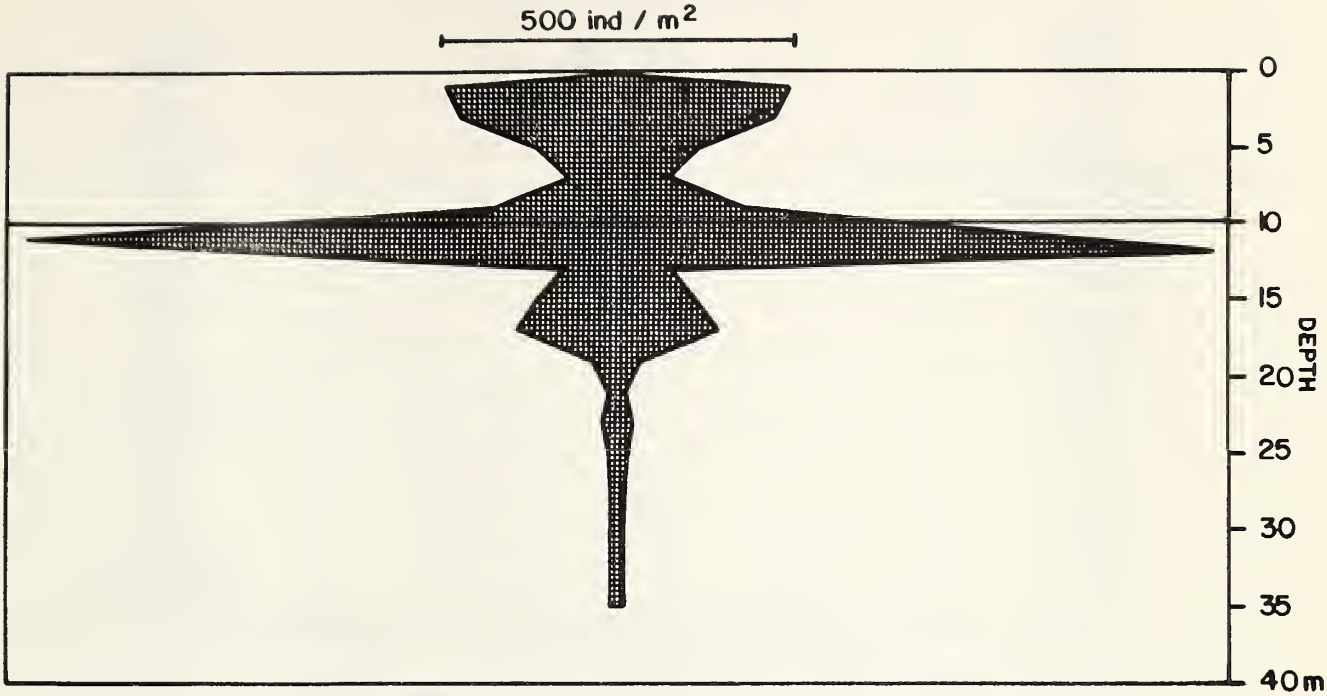
The bathymetrical distribution of the chironomid

species present in Barrier Reservoir are given in Figures 43 to 62 (except for Tendipes attenuatus which was only rarely recorded). A number of species are represented in all depth zones, namely Tendipes sp., Tanytarsus sp., Procladius nr. culiciformis, Calopsectra nr. confusa, Tanytarsus nr. nigricans, Harnischia nr. pseudotener, Stempellinella nr. brevis, and Trichocladius sp. Of these, only Tanytarsus nr. nigricans has maximal numbers per m^2 in the depth zones above the drawdown limit. Species which appear to be most affected by the drawdown as reflected by their numerical abundance, are Tanytarsus sp., Procladius nr. culiciformis, Stempellinella nr. brevis, and Harnischia nr. pseudotener. Of these species, Tanytarsus sp. is most markedly influenced by the fluctuation of water levels. This species has an average abundance of 3345 ind. per m^2 in the depth zone 10.5 - 12 metres, with a maximum value of 5560 ind. per m^2.

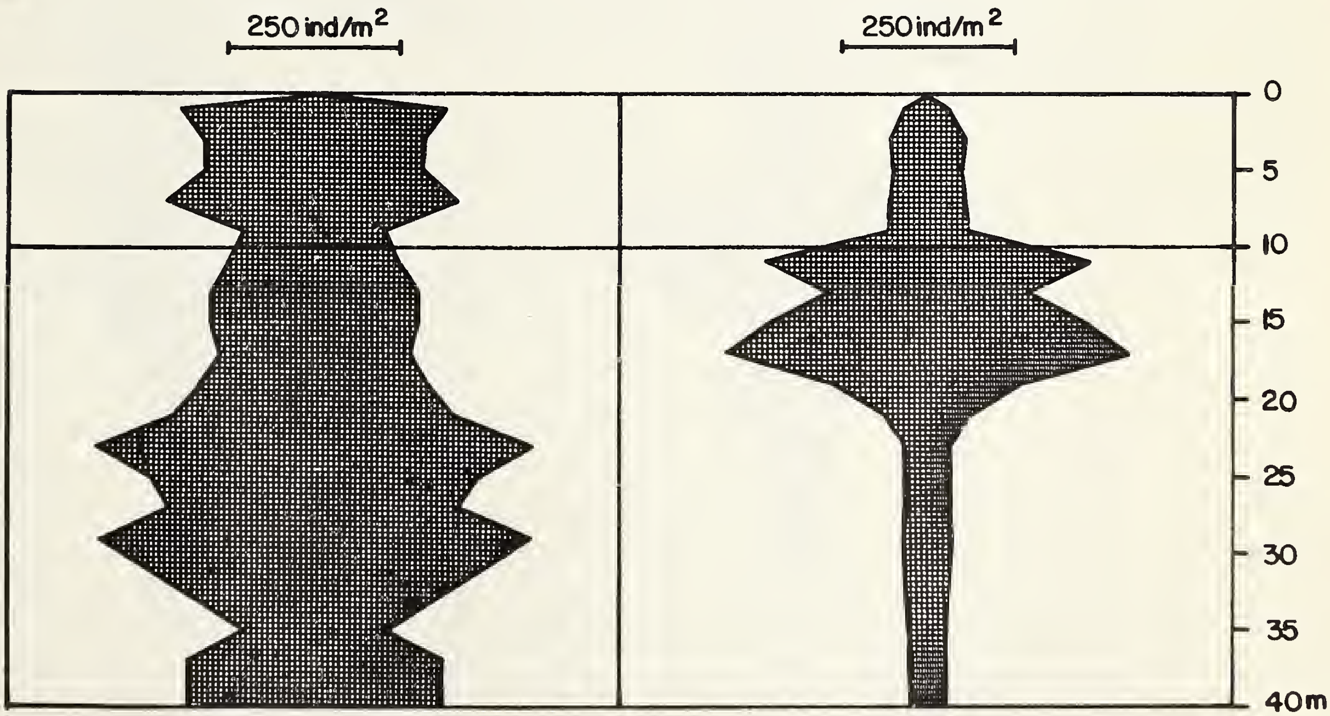
All of the species with wide bathymetric limits, with the exception of Tendipes sp. and Calopsectra nr. confusa, tend to decrease in numbers with increasing depth. Tendipes sp. achieves maximal numbers in the middle profundal and relatively large numbers in the deepest profundal. Calopsectra nr. confusa is little affected by increasing depth, with littoral and profundal abundances almost equal.

Species found down through the upper profundal are Pentaneura (melanops gp.) sp., Prodiamesa (Monodiamesa) sp., Psectrocladius sp. 1, Psectrocladius sp. 2, and Diames-

Average bathymetrical distribution of _Tanytarsus_ sp. (FIG. 43.), _Tendipes_ sp. (FIG. 44.), and _Procladius_ nr. _culiciformis_ (FIG. 45.) in Barrier Reservoir.


500 ind / m2
0
5
10
15
20
25
30
35
40m
DEPTH

43.


250 ind/m2
250 ind/m2
0
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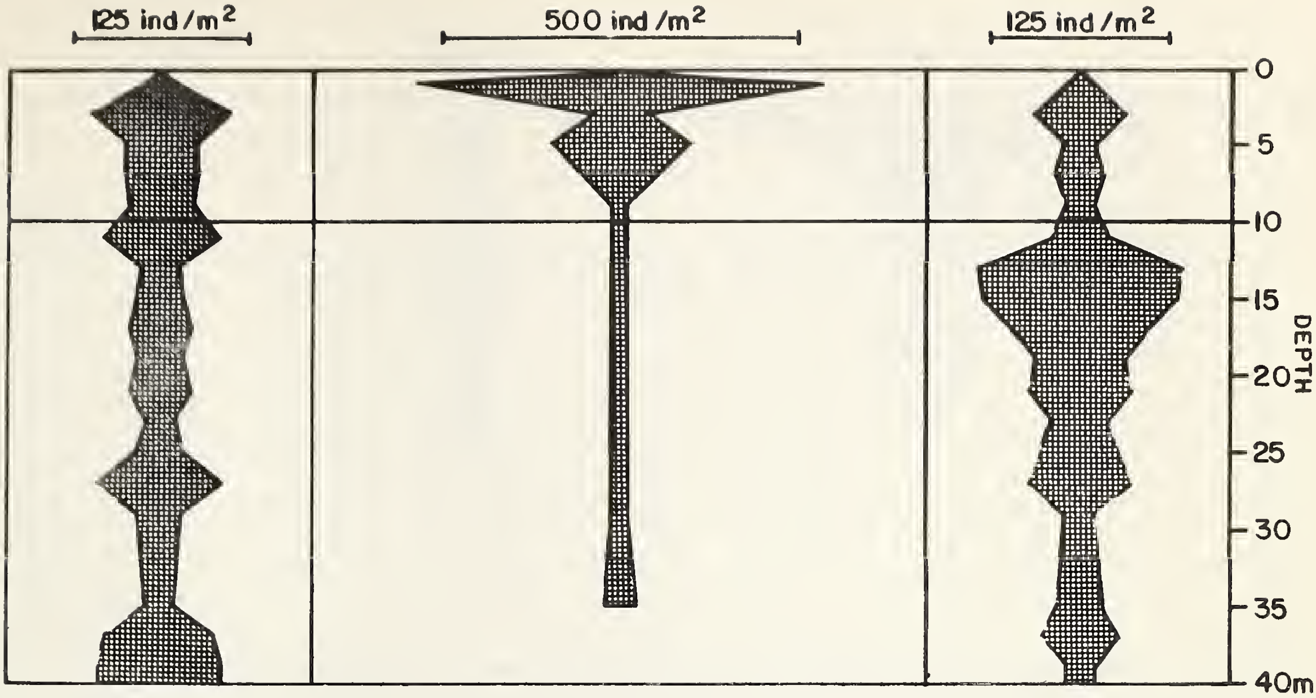
40m

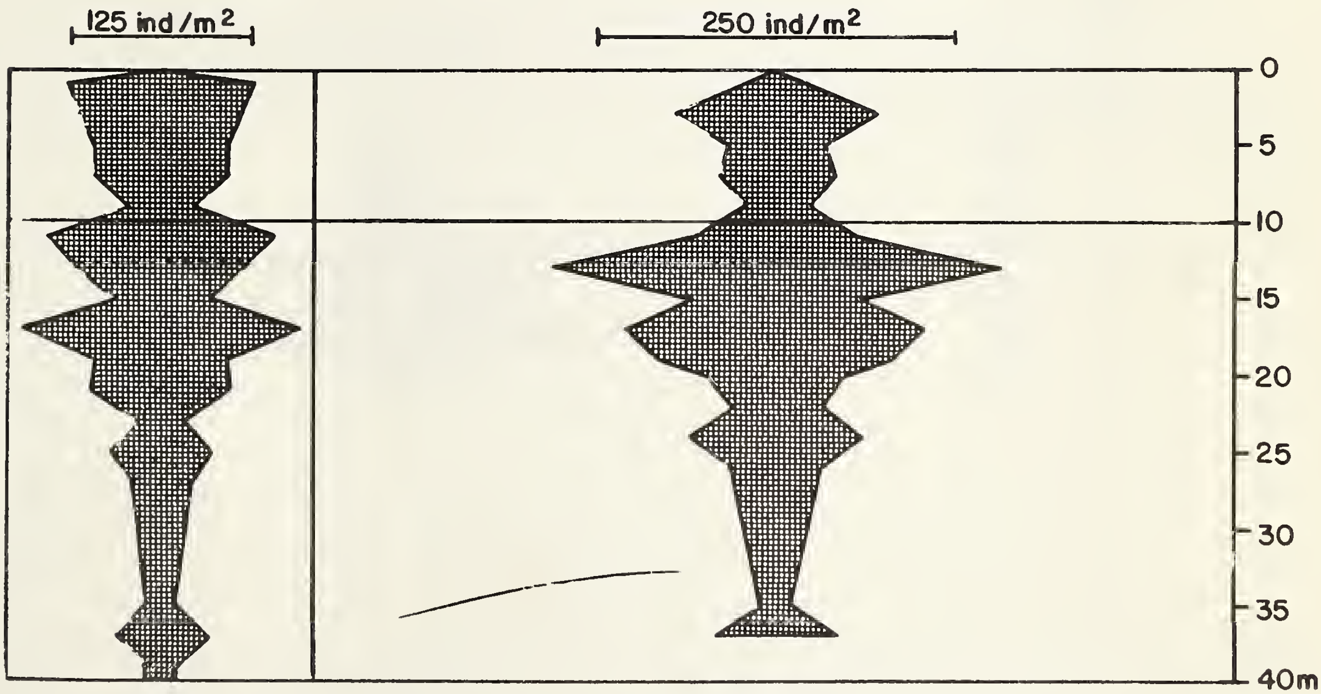
44.

45.

Average bathymetrical distribution of *Calopsectra* nr. *confusa* (FIG. 46.), *Tanytarsus* nr. *nigricans* (FIG. 47.), *Harnischia* nr. *pseudotener* (FIG. 48.), *Trichocladius* sp. (FIG. 49.), and *Stempellinella* nr. *brevis* (FIG. 50.) in Barrier Reservoir.

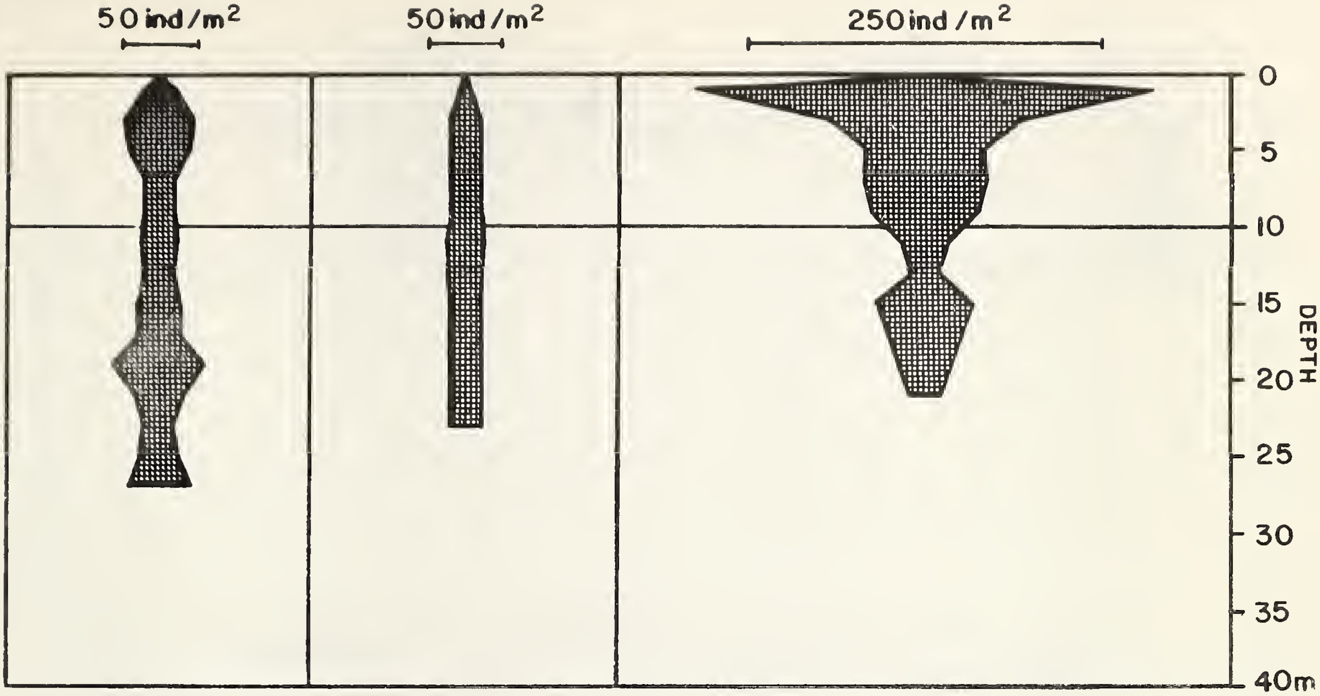

125 ind/m²
500 ind/m²
125 ind/m²
0
5
10
15
20
25
30
35
40m
DEPTH

46. 47. 48.


125 ind/m²
250 ind/m²
0
5
10
15
20
25
30
35
40m

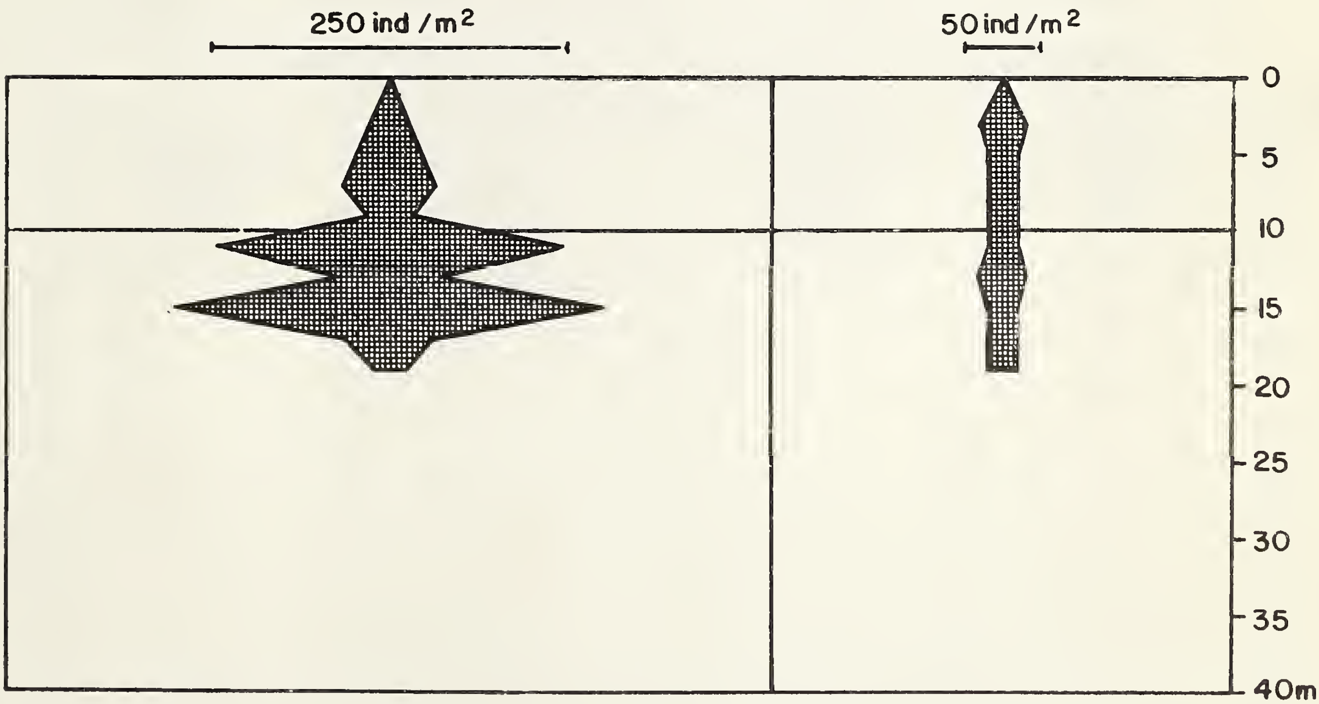
49. 50.

Average bathymetrical distribution of _Pentaneura_ (_mel-anops_ gp.) sp. (FIG. 51.), _Prodiamesa_ sp. (FIG. 52.), _Psectrocladius_ sp. 2 (FIG. 53.), _Psectrocladius_ sp. 1 (FIG. 54.), and Diamesinae sp. (FIG. 55) in Barrier Reservoir.



50 ind/m²
50 ind/m²
250 ind/m²
0
5
10
15
20
25
30
35
40m
DEPTH

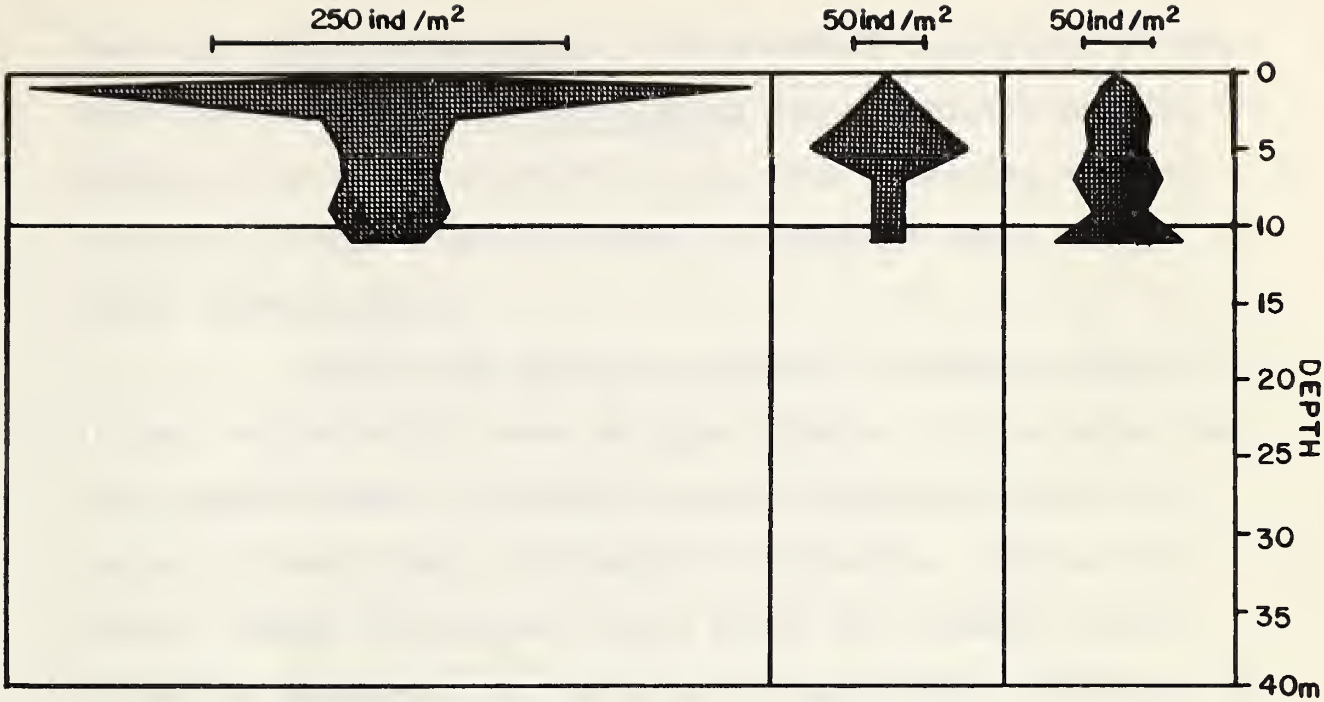
51. 52. 53.



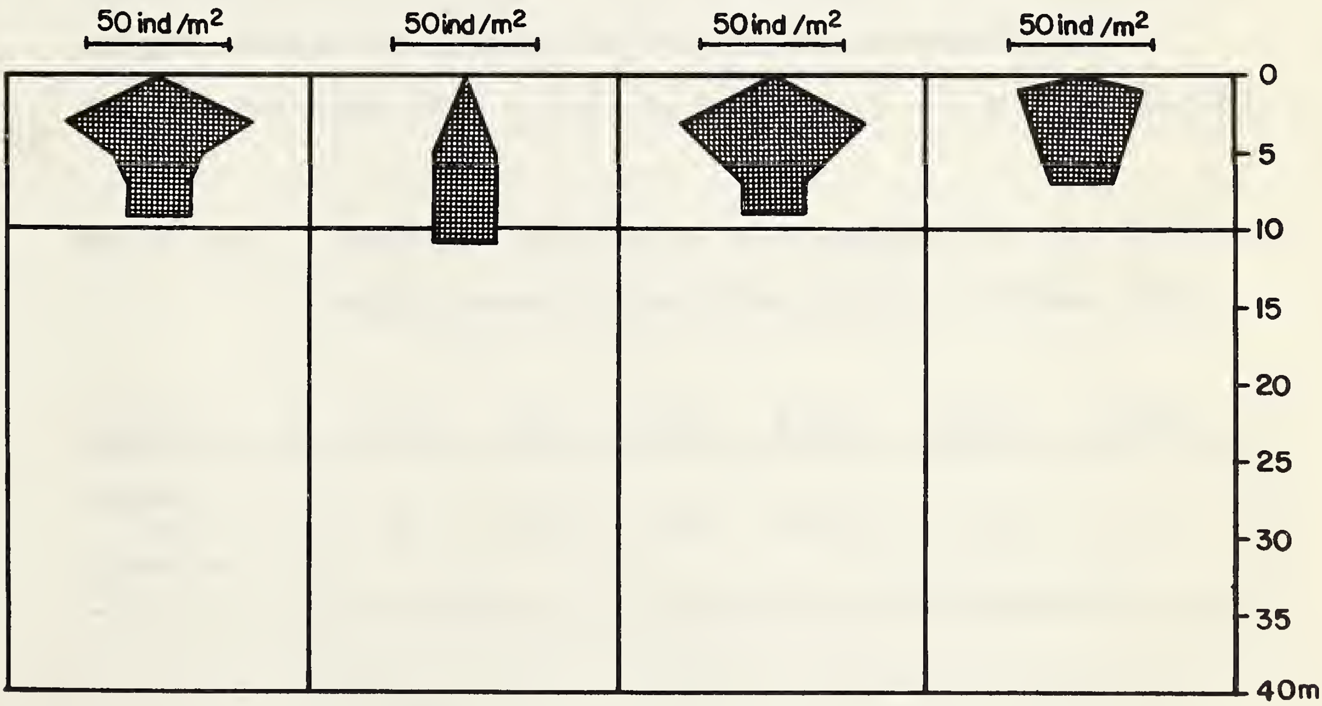
250 ind/m²
50 ind/m²
0
5
10
15
20
25
30
35
40m

54. 55.

Average bathymetrical distribution of _Tendipes_ nr. _riparius_ (FIG. 56.), _Harnischia_ nr. _nais_ (FIG. 57.), _Polypedilum_ (_fallax_ gp.) (FIG. 58.), _Odontomesa_ nr. _fulva_ (FIG. 59.), _Diamesa_ nr. _nivoriunda_ (FIG. 60.), _Cryptochironomus_ nr. _fulvus_ (FIG. 61.), and _Prodiamesa_ nr. _olivacea_ (FIG. 62.) in Barrier Reservoir.



56. 57. 58.



59. 60. 61. 62.

inae sp. Psectrocladius sp. 2 is markedly orientated to the upper littoral while Psectrocladius sp. 1 achieves maximal abundance below the drawdown limit. The remaining species included, retain constant numbers throughout their bathymetric distributions.

Table XXIV gives the numbers of species present in the various depth zones of Lake Blåsjön. It is noted that the largest number of species occurs immediately below the region of water level fluctuation in Blåsjön, whereas the largest number of species occurs above the drawdown limit in Barrier Reservoir as indicated in Table XXVI. However, the drawdown limit in Barrier Reservoir is much lower; if only depths are noted, it will be seen that both lakes have the largest number of species in the region encompassing the eight metre zone (2.5 - 8 m. in Barrier; 5 - 8 m. in Blåsjön).

Table XXIV. Number of species of chironomids for the different depth zones in Lake Blåsjön (from Grimås, 1961).

Depth m.	2-4	5-6	7-8	8-10	10-13	13-20
Number of Species	4	10	20	12	11	4

A similar study indicated the following distribution of chironomids for the unregulated Swedish lake, Ankarvattnet (Table XXV).

Table XXV. Number of species of chironomids for the different depth zones in Lake Ankarvattnet (from Grimås, 1961).

Depth m.	2-4	5-6	10-12
Number of Species	44	20	4

As is characteristic for the majority of unregulated lakes, the largest number of species is confined to the upper littoral (2 - 4 m.). This is to be expected as this region contains the most varied environmental conditions present in a given lake. Thus, it can be seen that qualitative and quantitative losses are experienced in regulated lakes. These losses have been determined by Grimås (1961); by comparing the similar Swedish lakes, Blåsjön and Ankarvattnet, he has calculated the qualitative losses as 80% for the regulated portion of the littoral region, and for the entire littoral as 60%. Losses are also accrued by the deeper regions as indicated in Figure 23.

Table XXVI includes the percentages of different species of larval chironomids in the various depth zones during the present investigation.

Table XXVI. The percentages of the different species of chironomids for the various depth zones in Barrier Reservoir. (Data includes figures from 1960 - 1962).

Depth	Species	Actual Nos.	%
0 -2 m	_Tendipes_ sp.	334	33.8
	Tendipes nr. _riparius_	259	26.2
	Tanytarsus nr. _nigricans_	158	16.0
	Tanytarsus sp.	157	15.9
	Psectrocladius sp. 2	30	3.0
	Procladius nr. _culiciformis_	24	2.4
	Trichocladius sp.	12	1.2
	Prodiamesa nr. _olivacea_	4	<.1
	Tendipes _attenuatus_	2	<.1
	Stempellinella nr. _brevis_	2	<.1
	Calopsectra nr. _confusa_	1	<.1
	Cryptochironomus nr. _fulvus_	1	<.1
	Polypedilum (_fallax_ gp.)	1	<.1
	Pentaneura (_melanops_ gp.) sp.	1	<.1

TOTAL NO. OF SPP. 14 — TOTAL NO. OF INDIVIDUALS 986

continued

Table XXVI. (continued).

Depth	Species	Actual Nos.	%
2.5-8 m	Tendipes sp.	1339	35.5
	Tanytarsus sp.	1127	29.9
	Psectrocladius sp. 2	248	6.6
	Procladius nr. culiciformis	209	5.5
	Trichocladius sp.	179	4.8
	Tendipes nr. riparius	144	3.8
	Stempellinella nr. brevis	138	3.6
	Tanytarsus nr. nigricans	135	3.6
	Calopsectra nr. confusa	108	2.8
	Polypedilum (fallax gp.)	34	.9
	Harnischia nr. nais	32	.9
	Pentaneura (melanops gp.) sp.	23	.6
	Cryptochironomus nr. fulvus	12	.3
	Harnischia nr. pseudotener	9	.2
	Prodiamesa sp.	8	.2
	Odontomesa nr. fulva	7	.2
	Diamesinae sp.	6	.2
	Psectrocladius sp. 1	3	<.1
	Prodiamesa nr. olivacea	1	<.1
	Diamesa nr. nivoriunda	1	<.1
	TOTAL NO. OF SPP. 20	TOTAL NO. OF INDIVIDUALS 3763	

continued

Table XXVI. (continued).

Depth	Species	Actual Nos.	%
8.5-10 m	Tanytarsus sp.	647	51.0
	Tendipes sp.	310	24.4
	Procladius nr. culiciformis	135	10.6
	Psectrocladius sp. 2	40	3.2
	Tendipes nr. riparius	34	2.7
	Calopsectra nr. confusa	27	2.1
	Trichocladius sp.	25	2.0
	Stempellinella nr. brevis	19	1.5
	Polypedilum (fallax gp.)	14	1.1
	Prodiamesa sp.	4	.3
	Psectrocladius sp. 1	3	.2
	Pentaneura (melanops gp.) sp.	2	.2
	Harnischia nr. pseudotener	2	.2
	Harnischia nr. nais	1	<.1
	Cryptochironomus nr. fulvus	1	<.1
	Tanytarsus nr. nigricans	1	<.1
	Odontomesa nr. fulva	1	<.1
	Prodiamesa nr. olivacea	1	<.1
	Diamesa nr. nivoriunda	1	<.1
	# Diamesinae sp.	-	-

TOTAL NO. OF SPP. 20	TOTAL NO. OF INDIVIDUALS 1268

continued

Table XXVI. (continued).

Depth	Species	Actual Nos.	%
10.5-12 m	Tanytarsus sp.	2794	63.3
	Procladius nr. culiciformis	886	20.1
	Tendipes sp.	407	9.2
	Psectrocladius sp. 1	79	1.8
	Trichocladius sp.	67	1.5
	Calopsectra nr. confusa	60	1.4
	Stempellinella nr. brevis	53	1.2
	Harnischia nr. pseudotener	16	.4
	Psectrocladius sp. 2	12	.3
	Pentaneura (melanops gp.) sp.	12	.3
	Polypedilum (fallax gp.)	12	.3
	Tendipes nr. riparius	7	.2
	Prodiamesa sp.	7	.2
	Harnischia nr. nais	2	<.1
	Diamesa nr. nivoriunda	1	<.1
	Diamesinae sp.	1	<.1
	# Tanytarsus nr. nigricans	-	-
	TOTAL NO. OF SPP. 17	TOTAL NO. OF INDIVIDUALS 4416	

continued

Table XXVI. (continued).

Depth	Species	Actual Nos.	%
12.5-14 m	*Tendipes* sp.	123	23.2
	Procladius nr. *culiciformis*	121	22.8
	Stempellinella nr. *brevis*	97	18.3
	Tanytarsus sp.	69	13.0
	Harnischia nr. *pseudotener*	54	10.2
	Trichocladius sp.	45	8.5
	Psectrocladius sp.	13	2.4
	Calopsectra nr. *confusa*	4	.8
	Diamesinae sp.	3	.6
	Psectrocladius sp. 2	1	.2
	Pentaneura (*melanops* gp.) sp.	1	.2
	#*Tanytarsus* nr. *nigricans*	-	-
	#*Prodiamesa* sp.	-	-
	TOTAL NO. OF SPP. 13	TOTAL NO. OF INDIVIDUALS 531	

continued

Table XXVI. (continued).

Depth	Species	Actual Nos.	%
14.5-20 m	Procladius nr. culiciformis	1357	39.4
	Tendipes sp.	923	26.8
	Tanytarsus sp.	503	14.6
	Stempellinella nr. brevis	235	6.8
	Harnischia nr. pseudotener	164	4.8
	Trichocladius sp.	160	4.6
	Psectrocladius sp. 1	32	.9
	Calopsectra nr. confusa	27	.8
	Pentaneura (melanops gp.) sp.	27	.8
	Psectrocladius sp. 2	6	.2
	Diamesinae sp.	6	.2
	Prodiamesa sp.	3	<.1
	Tanytarsus nr. nigricans	2	<.1
	TOTAL NO. OF SPP. 13	TOTAL NO. OF INDIVIDUALS 3445	

continued

Table XXVI. (continued).

Depth	Species	Actual Nos.	%
20.5-30 m	Tendipes sp.	1722	73.5
	Procladius nr. culiciformis	276	11.8
	Harnischia nr. pseudotener	95	4.0
	Trichocladius sp.	92	3.9
	Stempellinella nr. brevis	88	3.8
	Calopsectra nr. confusa	25	1.1
	Tanytarsus sp.	20	.9
	Pentaneura (melanops gp.) sp.	19	.8
	Tanytarsus nr. nigricans	4	.2
	Psectrocladius sp. 2	1	<.1
	Prodiamesa sp.	1	<.1
	TOTAL NO. OF SPP. 11	TOTAL NO. OF INDIVIDUALS 2343	
30.5-40 m	Tendipes sp.	131	70.4
	Procladius nr. culiciformis	17	9.1
	Calopsectra nr. confusa	15	8.1
	Harnischia nr. pseudotener	9	4.8
	Trichocladius sp.	6	3.2
	Stempellinella nr. brevis	5	2.7

continued

Table XXVI. (continued).

Depth	Species	Actual Nos.	%
30.5-40 m	Tanytarsus nr. nigricans	2	1.1
	Tanytarsus sp.	1	.5
	TOTAL NO. OF SPP. 8	TOTAL NO. OF INDIVIDUALS 186	

NOTE: Species indicated with #, although not recorded in the depth zone when indicated thusly, are recorded in the zone(s) below. (Tendipes attenuatus not included, as it was rarely recorded).

D. Upper and Lower Kananaskis Lakes

i. General

A series of nine dredgings were taken from Upper Kananaskis in 1936 and these indicated an average benthic fauna of 1243 ind. per m^2. The average weight of the standing crop of bottom fauna was 7.3 lbs. dry wt. per acre. In 1947, Rawson took a series of 26 dredgings; the average number of ind. per m^2 was 1245 and the average weight of the standing crop was equivalent to approximately 5.8 lbs. dry wt. per acre.

The reduction in weight was attributed to the decrease in molluscs, which represents 30% of the bottom fauna in 1936 while they represented 8% of the bottom fauna in 1947. A reduction in the numbers of amphipods from 1936 to 1947 was noted.

Lower Kananaskis Lake was sampled by Rawson in 1936 when four dredgings were taken. These dredgings showed similar values to those obtained in 1947, when 16 dredgings were taken. There were an average of 1672 ind. per m^2 in 1947 with an average dry weight for the standing crop of 7.1 lbs. per acre. Table XXVII summarizes the data given by Rawson (1948).

Table XXVII. Bottom fauna analysis from Upper and Lower Kananaskis Lakes in 1947 (from Rawson, 1948).

	Average no./m^2	Chironomids	Oligochaetes	Amphipods	Pisidia	Gastropods	Miscellaneous
Lower Kananaskis Lake	1672	29%	11%	9%	50%	0.7%	1.2%
Upper Kananaskis Lake	1245	81%	9%	-	8%	-	2 %

Similar values were obtained for Lower Kananaskis Lake by Miller (1954) prior to impoundment of the lake.

Thomas (1957) investigated Lower Kananaskis Lake following impoundment. Table XXVIII gives the results of his bottom fauna analysis.

Table XXVIII. Dredgings from Lower Kananaskis Lake, August 21 and 23, 1957. (D) denotes dead individuals.

Stn. No.	Chironomids	Shrimps	Oligochaetes	Clams	Snails	Misc.
1	-	-	-	-	-	1
2	-	-	-	-	-	-
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	344	-	11	9	8	-
6	3	-	-	-	-	-
7	3	-	1	-	-	-
8	-	-	-	-	-	-
9	-	-	-	-	-	-
10	22	1	5	5(D)	21(D)	-
11	31	-	2	-	-	2
12	7	-	3	-	-	3
13	20	-	-	-	4(D)	-

Both Miller (1954) and Thomas (1957) predicted a decrease in the numbers of bottom forms with only the chironomid larvae likely to remain in significant numbers.

Upper and Lower Kananaskis Lakes were again investigated in 1961 and 1962. Although the miscellaneous groups were more abundant in these lakes as compared with Barrier Reservoir, only the chironomids, pisidia, and oligochaetes are considered in the overall analysis. Table XXIX gives the analysis of the two populations for 1961 and 1962.

Table XXIX. Composition of benthic fauna for Upper and Lower Kananaskis Lakes during 1961 and 1962.

		Average no./m^2	Chironomids	Pisidia	Oligochaetes
LKL	1961	2707	80.3%	16.2%	3.5%
	1962	2517	79.2%	14.9%	5.9%
UKL	1961	1889	76.8%	15.3%	7.9%
	1962	2235	89.2%	8.2%	2.6%

The results for Upper Kananaskis Lake are similar to the values Rawson gives for 1947, with perhaps a greater percentage of molluscs occurring. The effect of regulation can readily be seen by comparing Rawson's values for Lower Kananaskis Lake during 1947 with those obtained in 1961 and 1962. A very marked decrease has occurred in the percentage

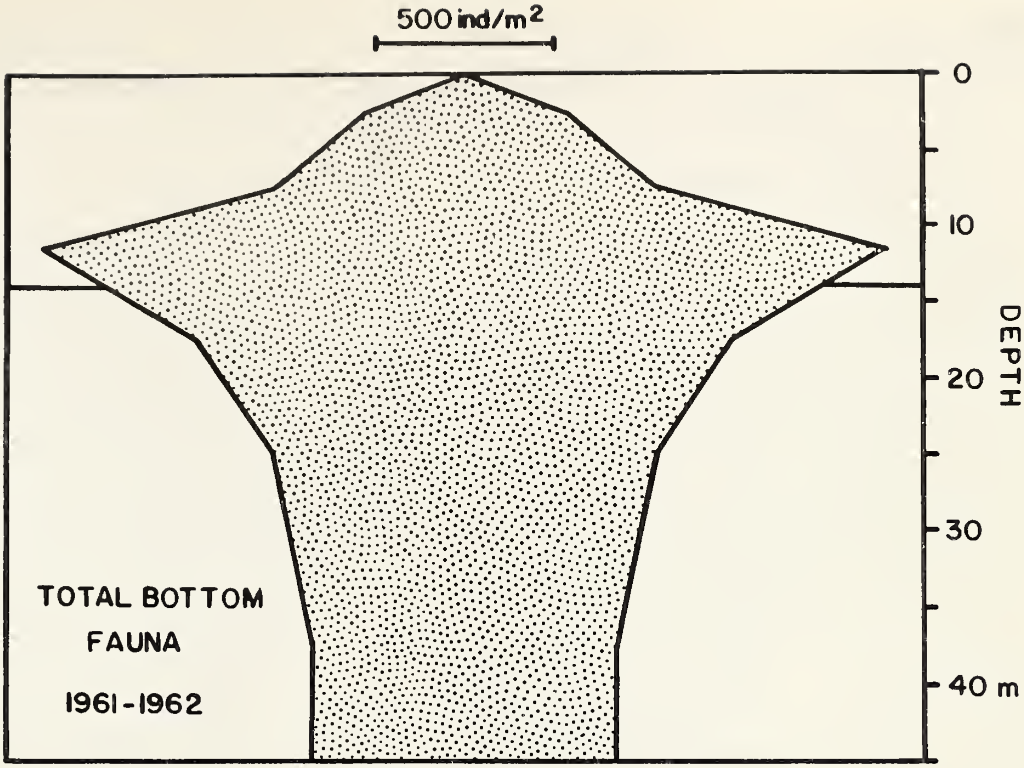
of pisidia present and to a lesser extent a reduction in the percentage of oligochaetes. The chironomids have risen to dominate the bottom fauna, as was noted above in the discussion of Barrier Reservoir, and with conditions found in reservoirs generally.

A marked increase is noted in the average numbers of individuals per metre^2 in comparing the present study with ones of the past; this is contrary to predictions of Miller and Thomas. The difference may be attributed to the present investigation using more effective sifting methods to retrieve the organisms present. This is suggested, as an actual increase in average numbers of individuals is not consistent with other investigations on reservoirs.

Taking the percentages of the major groups in the various depth zones (see Table XXX) indicates that pisidia do occur in appreciable numbers in the lower depth zones. That this is not the case in Barrier Reservoir may be attributed to the lack of deep profundal forms of this group which have not as yet invaded Barrier Reservoir. The percentage of pisidia in the 20 - 40 metre zone of Lower Kananaskis Lake in 1962 approaches the overall average of 50% given by Rawson (1948) for Lower Kananaskis Lake prior to impoundment.

The bathymetrical distributions of bottom fauna for the two lakes are given in Figures 63 and 64. From these figures it can be seen that the pisidia achieve maximal numbers below the drawdown limit in both Upper and Lower

FIG. 63. Average bathymetrical distribution of the total bottom fauna, and its components for Lower Kananaskis Lake, 1961 - 1962.


500 ind/m²
0
10
20
30
40 m
DEPTH
TOTAL BOTTOM FAUNA
1961-1962

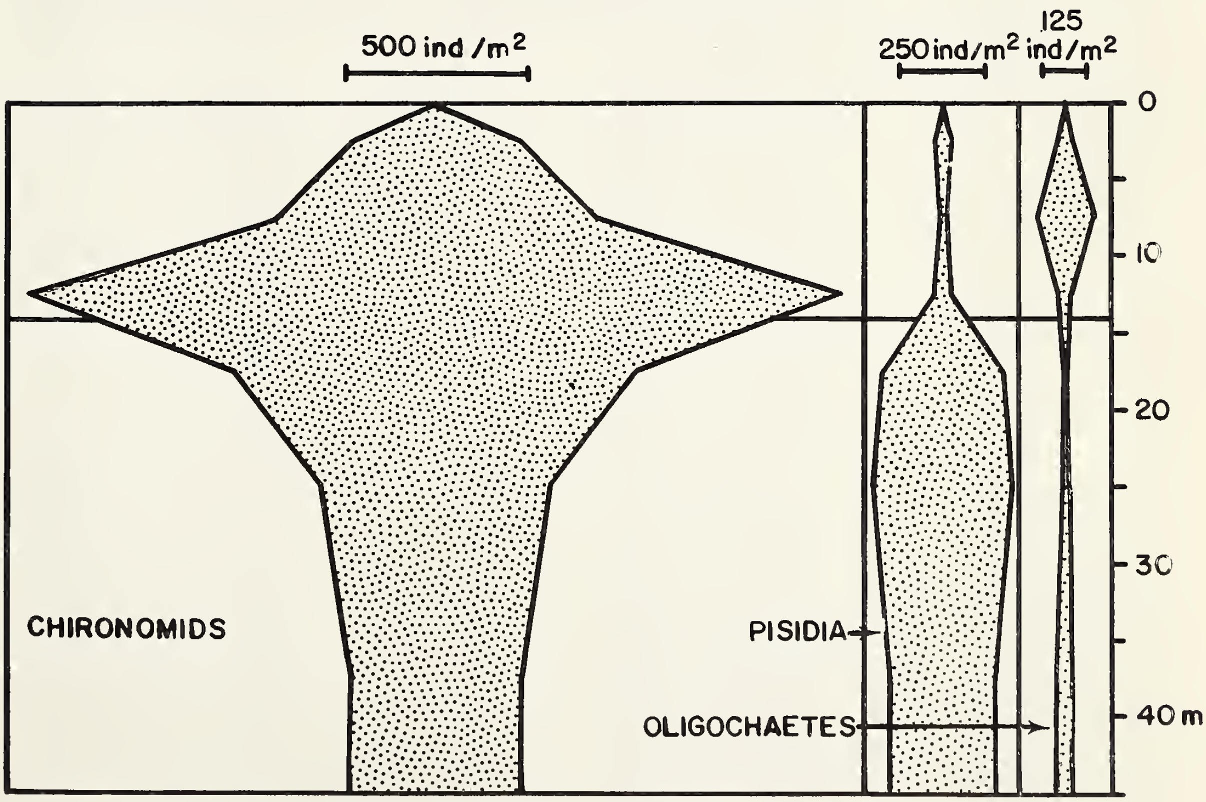
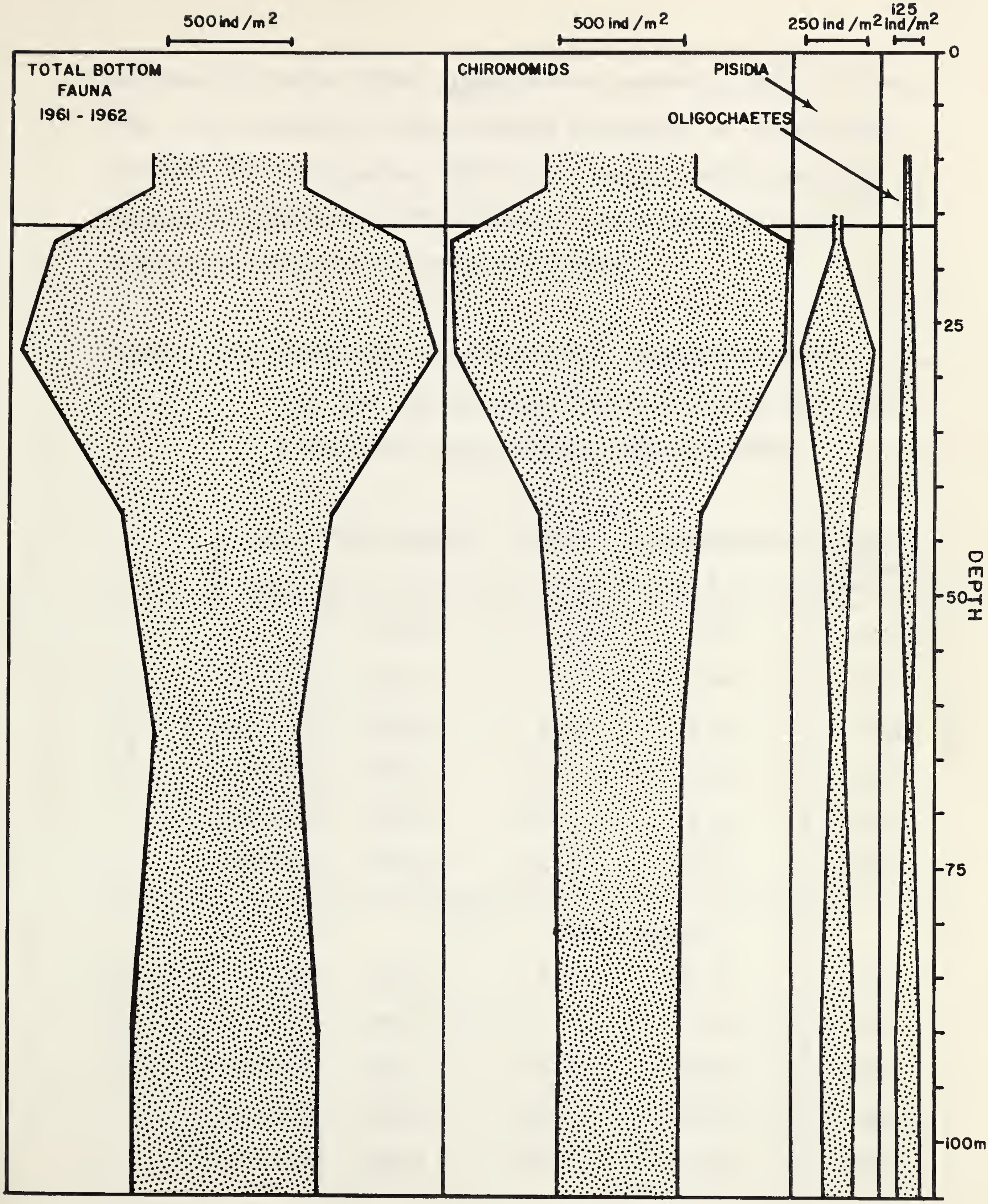

500 ind /m²
250 ind/m²
125 ind/m²
0
10
20
30
40 m
CHIRONOMIDS
PISIDIA
OLIGOCHAETES

FIG. 64. Average bathymetrical distribution of the total bottom fauna and its components for Upper Kananaskis Lake, 1961 - 1962.



500 ind/m2
500 ind/m2
250 ind/m2
125 ind/m2
TOTAL BOTTOM FAUNA 1961 - 1962
CHIRONOMIDS
PISIDIA
OLIGOCHAETES
0
25
50
75
100m
DEPTH

Kananaskis Lakes. The oligochaetes present a varied picture; the effectiveness of the sifting procedure is least satisfactory for this group. The chironomids tend to exhibit maximal numbers near the drawdown limit with decreasing abundance towards the deeper profundal.

Table XXX. Percentages of the major groups of benthic fauna for the various depth zones in Upper and Lower Kananaskis Lakes during 1961 and 1962.

		Depth (m)	Chironomids %	Pisidia %	Oligochaetes %	Total Numbers per m^2
		0 - 5	83.8	7.5	8.7	1146
L	1	5.5-10	97.2	1.4	1.4	2871
K	9	10.5-15	94.3	3.6	2.1	4819
L	6	15.5-20	66.4	32.2	1.4	3646
	1	20.5-30	65.6	30.3	4.1	1905
		30.5-45	58.2	31.6	10.2	1857
		0 - 5		not sampled		
L	1	5.5-10	57.2	3.6	39.2	1461
K	9	10.5-15	97.7	-	2.3	4784
L	6	15.5-20	90.7	8.4	0.9	2401
	2	20.5-30	57.9	41.6	0.5	2405
		30.5-45	57.9	40.2	1.9	1534

continued

Table XXX. (continued).

	Depth (m)	Chironomids %	Pisidia %	Oligochaetes %	Total Numbers per m^2
UKL 1961	0 - 9		not sampled		
	9.5-15	97.2	-	2.8	1232
	15.5-20	92.1	4.3	3.6	2797
	20.5-35	72.2	25.6	2.2	3323
	35.5-50	65.6	15.9	18.5	1164
	50.5-75		not sampled		
	75.5-105	41.2	28.3	30.5	929
UKL 1962	0 - 9		not sampled		
	9.5-15		not sampled		
	15.5-20	100	-	-	2802
	20.5-35	87.3	10.3	2.4	3267
	35.5-50	83.2	13.4	3.4	2177
	50.5-75	87.6	8.6	3.8	1146
	75.5-105	83.8	10.9	5.3	1784

Productivity has been calculated for both lakes from data collected in 1962; the lakes were sampled in July, August, and September of that year. The productivity as indicated by the standing crop of bottom fauna for that period is 5.45 kgm/ha or 4.80 lbs/acre for Upper Kananaskis Lake; the value 6.21 kgm/ha or 5.46 lbs/acre is given for Lower Kananaskis Lake.

These values are somewhat less than those given by Rawson for 1947, though a drop was to be expected following regulation of Lower Kananaskis Lake.

Thus, the amount of productivity as calculated from standing crops of bottom fauna increases going from Upper Kananaskis Lake --- Lower Kananaskis Lake ---- Barrier Reservoir; this is a change from the situation in 1947 which gave the amount of productivity in this order; increasing from Barrier Reservoir ---- Upper Kananaskis Lake ---- Lower Kananaskis Lake.

ii. Chironomid Fauna

The number of chironomid species appears to be less in Upper and Lower Kananaskis Lakes as compared with Barrier Reservoir; this difference may be due to the rather scanty sampling, as regards determining species composition, of Upper and Lower Kananaskis Lakes relative to Barrier Reservoir. Eight species were recorded for Upper Kananaskis Lake and nine species for Lower Kananaskis Lake.

Tables XXXI and XXXII give an analysis of the percentages of the major groups present according to depth zones. Values were calculated from average numbers of individuals in a given depth zone; average, rather than actual numbers are used, as there is unequal sampling of the various depth zones.

Table XXXI. Percentages of the major groups of chironomids for the various depth zones in Lower Kananaskis Lake during 1961 and 1962. (Based on number of individuals for each group.)

Depth m.	2.5-12	14.5-16	16.5-20	20.5-30	30.5-40	Average
Tanypodinae	10.6	3.4	22.0	16.7	42.6	15.7
Orthocladiinae	4.7	38.3	1.4	1.3	2.9	6.9
Chironomini	17.9	42.5	28.7	31.2	23.5	23.9
Tanytarsini	66.8	15.8	47.9	50.8	31.0	53.5
No. of species	9	8	8	8	8	9

Table XXXII. Percentages of the major groups of chironomids for the various depth zones in Upper Kananaskis Lake during 1961 and 1962. (Based on number of individuals for each group.)

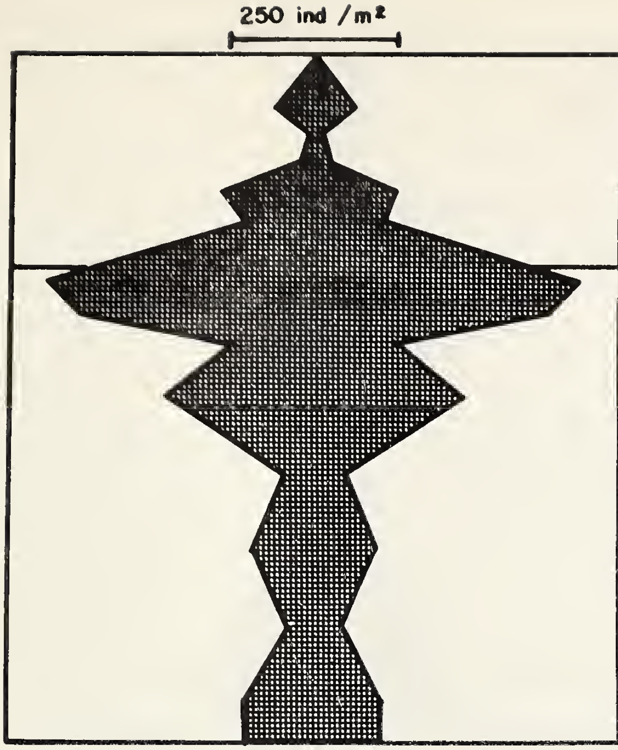
Depth m.	12.5-14	18.5-20	20.5-25	25.5-50	50.5-80	80.5-105	Average
Tanypodinae	8.5	12.8	12.3	9.9	25.0	19.1	14.6
Orthocladiinae	8.5	9.0	8.5	32.8	67.0	51.0	29.5
Chironomini	45.8	28.8	25.1	22.5	5.7	10.1	23.0
Tanytarsini	37.2	49.4	54.1	34.8	2.3	19.8	32.9
No. of species	6	6	6	6	6	6	6

Lower Kananaskis Lake is dominated by the Chironomini and Tanytarsini in general, throughout the depth zones. The Orthocladiinae assume a dominant position in the upper profundal (14.5 - 16 m.) while the Tanypodinae are the dominant forms in the lowest profundal regions (30.5 - 40 m.). This situation is similar to that in Barrier Reservoir (cf. Table XXX), but in Lower Kananaskis Lake the Orthocladiinae have assumed a larger portion of the fauna as have the Tanytarsini, while the Chironomini have been reduced.

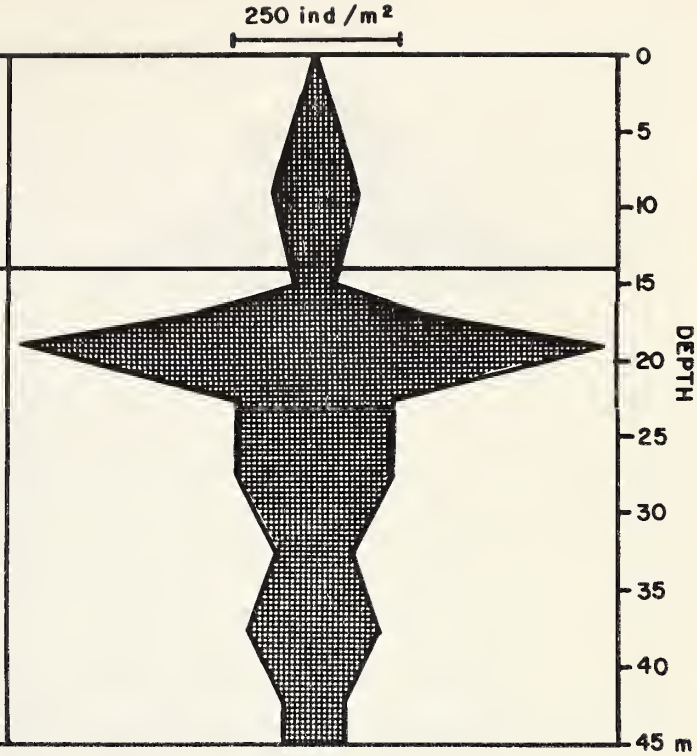
Upper Kananaskis Lake has a bathymetrical distribution of chironomids similar to that proposed by Brundin (1951) for very deep oligotrophic lakes. While Brundin based his description on the species numbers, as well as the number of individuals, the picture for the Upper and Lower Kananaskis Lakes are based on the numbers of individuals primarily. Brundin points out that the Tanytarsini reach their maximal abundance at moderate depths whereas the deepest zones are dominated by the Orthocladiinae larvae. This increase in the numbers of Orthocladiinae is evidenced below the 50 metre region in Upper Kananaskis Lake. Although the same Orthocladiinae species, Trichocladius sp., is present in all three reservoirs studied, it is only in the very deep Upper Kananaskis Lake that it predominates the profundal region.

The bathymetrical distribution of the chironomid larvae are given in Figures 65 to 73. Of the nine species

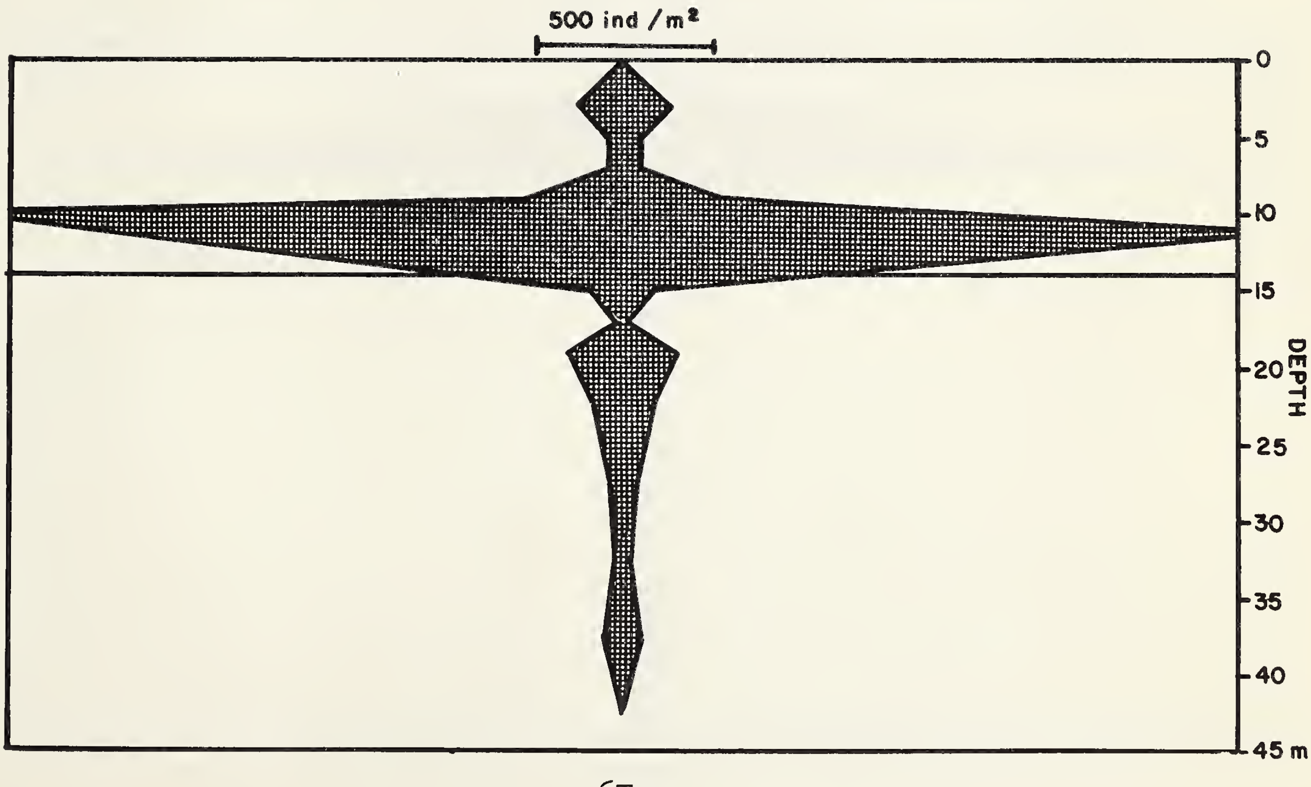
Average bathymetrical distribution of *Tendipes* sp. (FIG. 65.), *Tanytarsus* sp. (FIG. 66.), and *Calopsectra* nr. *confusa* (FIG. 67.) in Lower Kananaskis Lake.


250 ind / m²
0
5
10
15
20
25
30
35
40
45 m
DEPTH

65.

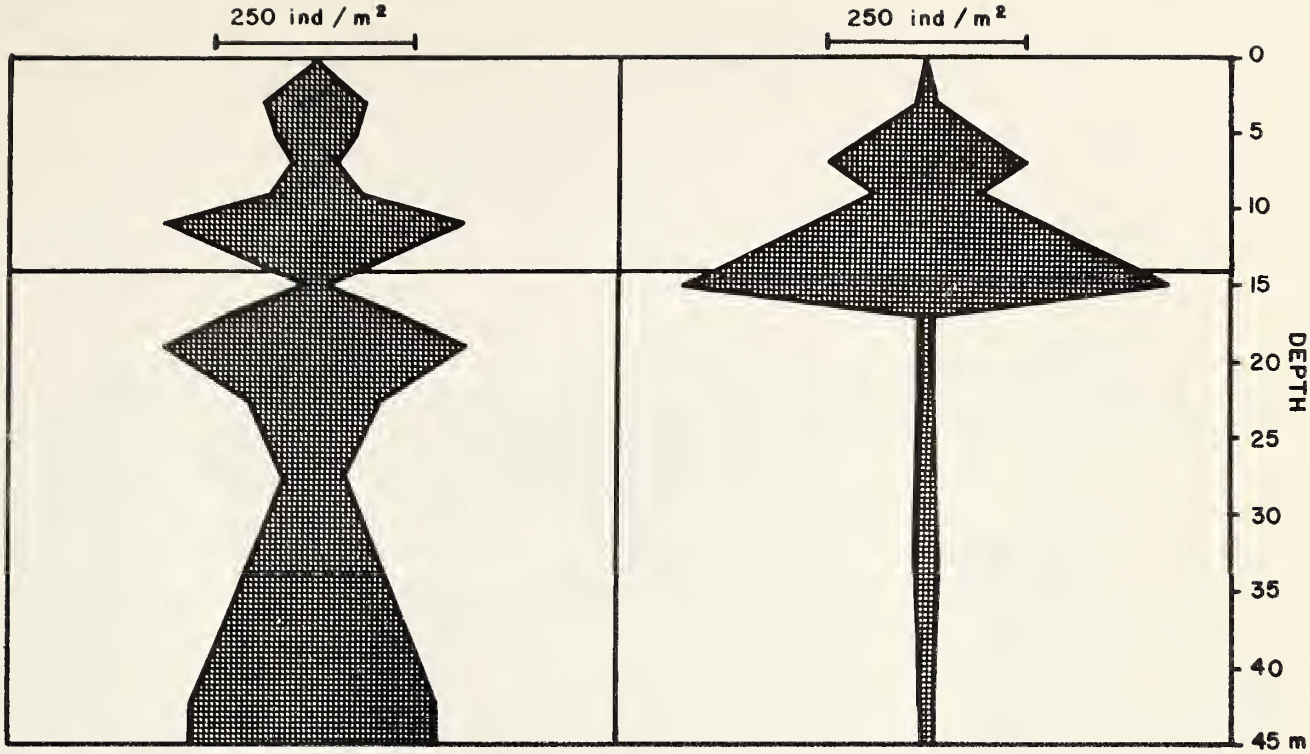

250 ind / m²

66.


500 ind / m²
0
5
10
15
20
25
30
35
40
45 m
DEPTH

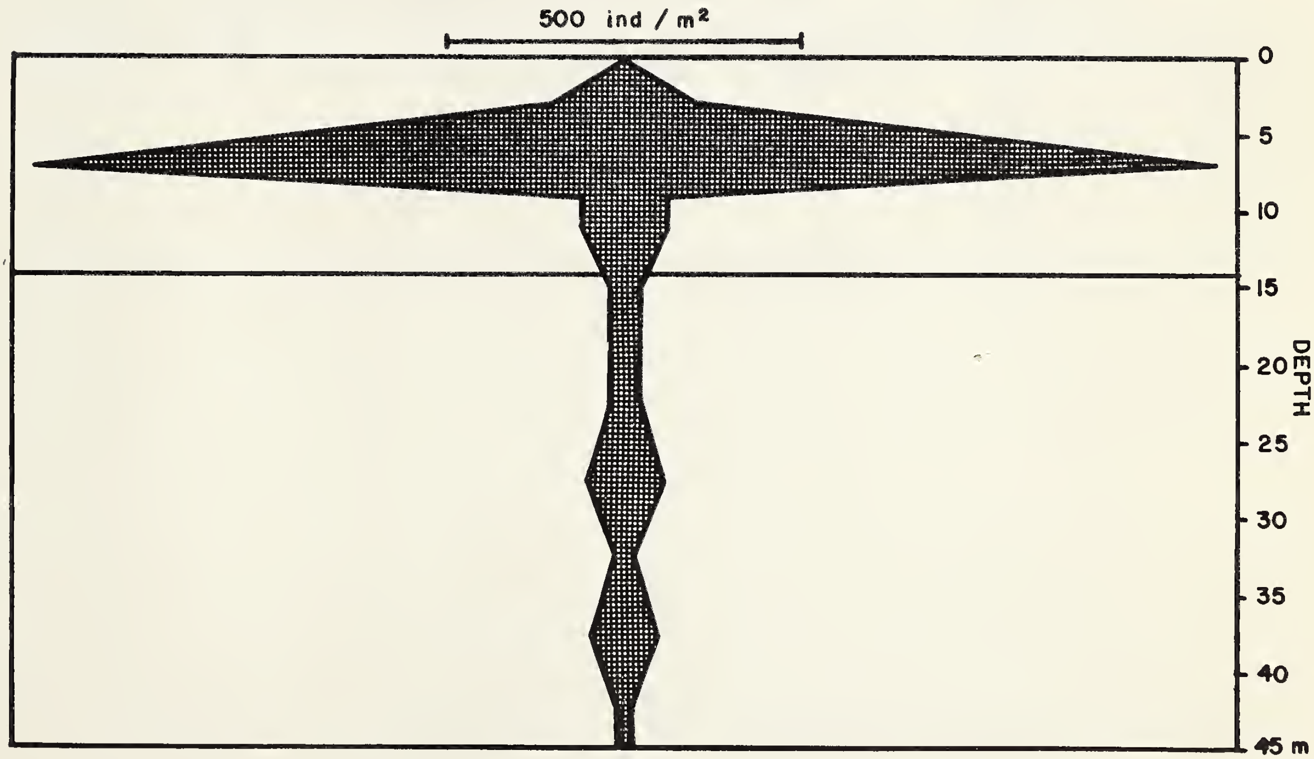
67.

Average bathymetrical distribution of *Procladius* nr. *culiciformis* (FIG. 68.), *Trichocladius* sp. (FIG. 69.), and *Tanytarsus* nr. *nigricans* (FIG. 70.) in Lower Kananaskis.


250 ind / m²
250 ind / m²
0
5
10
15
20
25
30
35
40
45 m
DEPTH

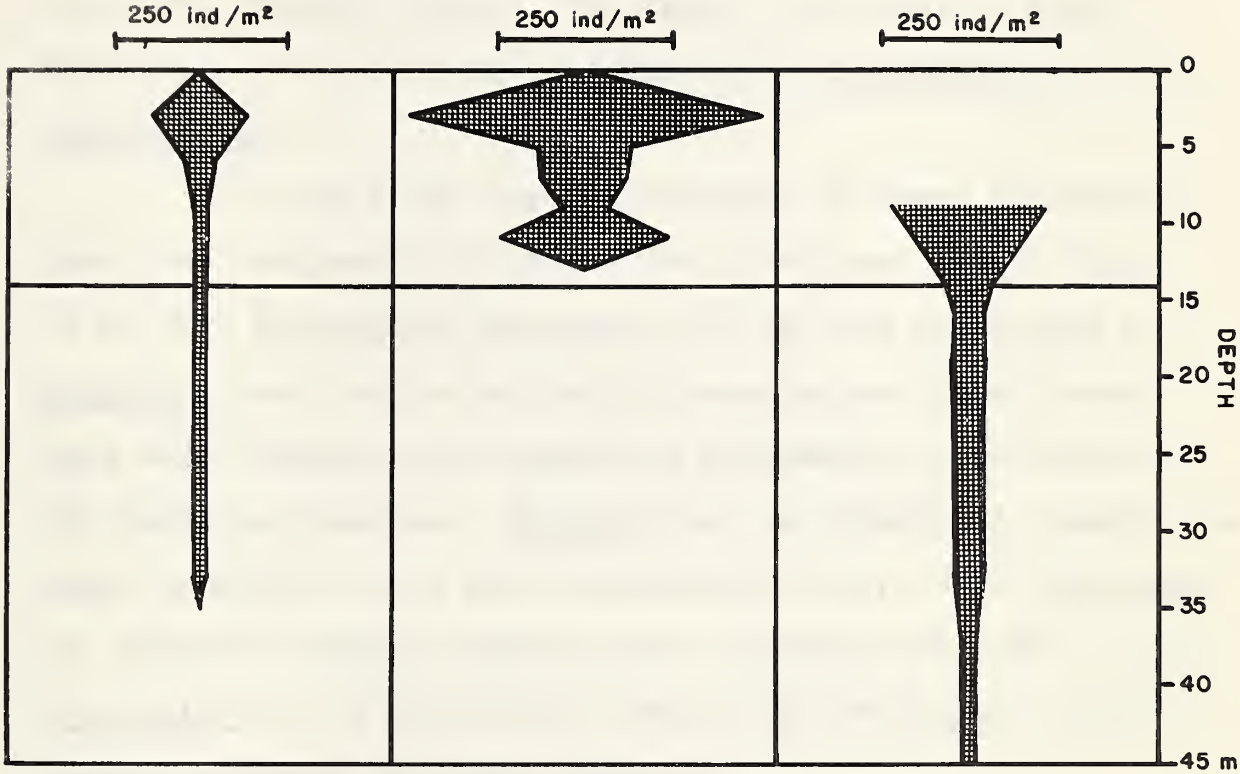
68.

69.


500 ind / m²
0
5
10
15
20
25
30
35
40
45 m
DEPTH

70.

Average bathymetrical distribution of <u>Pentaneura</u> (<u>mel-anops</u> gp.) sp. (FIG. 71.), <u>Tendipes</u> nr. <u>riparius</u> (FIG. 72.), and Diamesinae sp. (FIG. 73.) in Lower Kananaskis Lake.



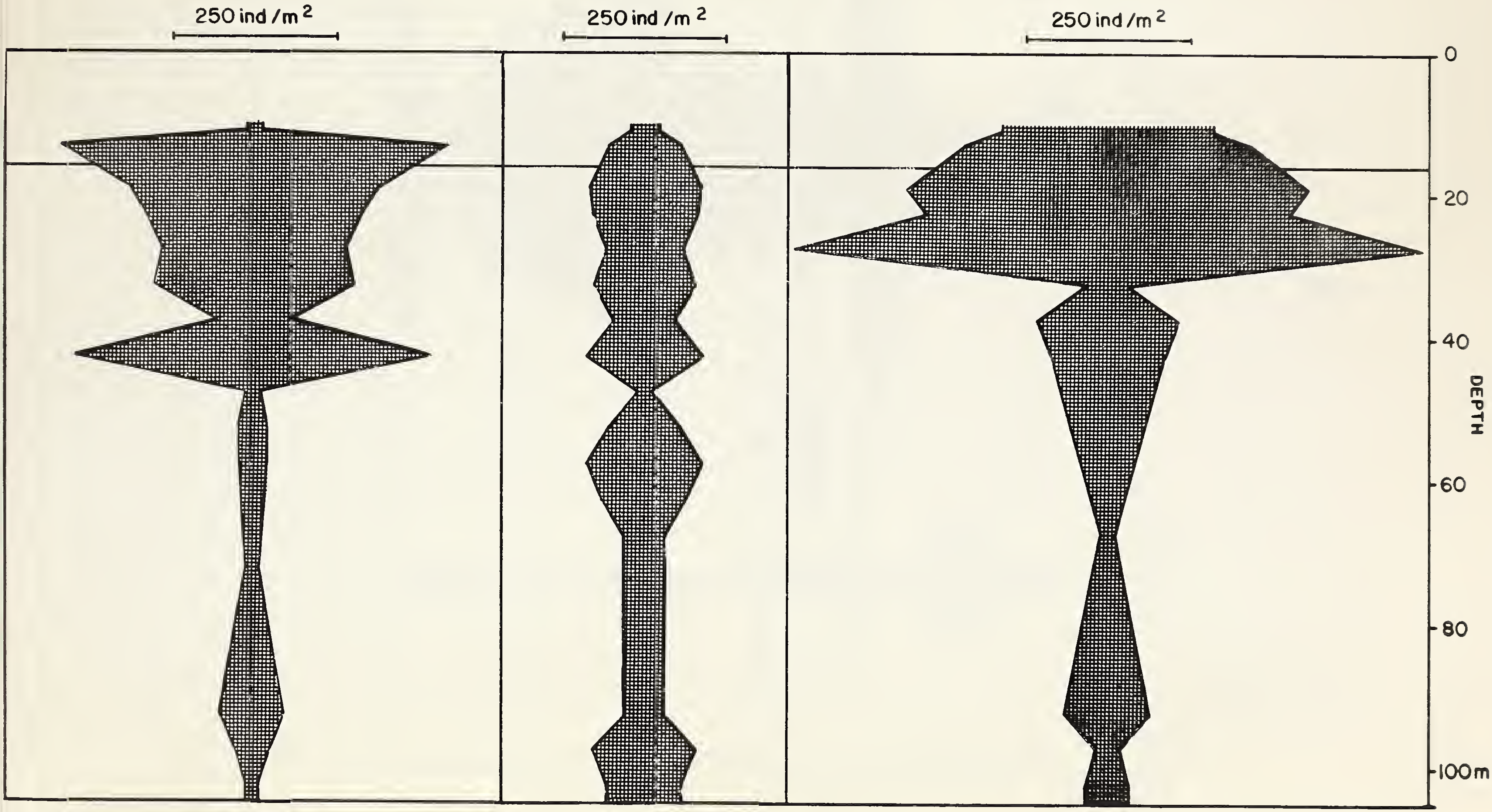
71. 72. 73.

present in Lower Kananaskis Lake, all but _Tendipes_ nr. _riparius_ have wide bathymetric limits. _Tendipes_ sp. is orientated towards the upper profundal, unlike the situation in Barrier Reservoir. _Tanytarsus_ sp. reaches maximal numbers below the drawdown limit. The deeper profundal of Lower Kananaskis Lake tends to be dominated by _Procladius_ nr. _culiciformis_.

Of the eight species recorded in Upper Kananaskis Lake, the bathymetric distribution of six are given (Figs. 74 to 79); _Pentaneura_ (_melanops_ gp.) sp. and _Tanytarsus_ nr. _nigricans_ were only occasionally recorded and insufficient data were obtained for suggesting bathymetric distributions for these two species. _Tendipes_ sp. is orientated towards the upper profundal as in Lower Kananaskis Lake, while _Tanytarsus_ sp. achieves maximal numbers below the drawdown limit. _Trichocladius_ sp. is orientated towards the profundal and dominates the lower profundal markedly.

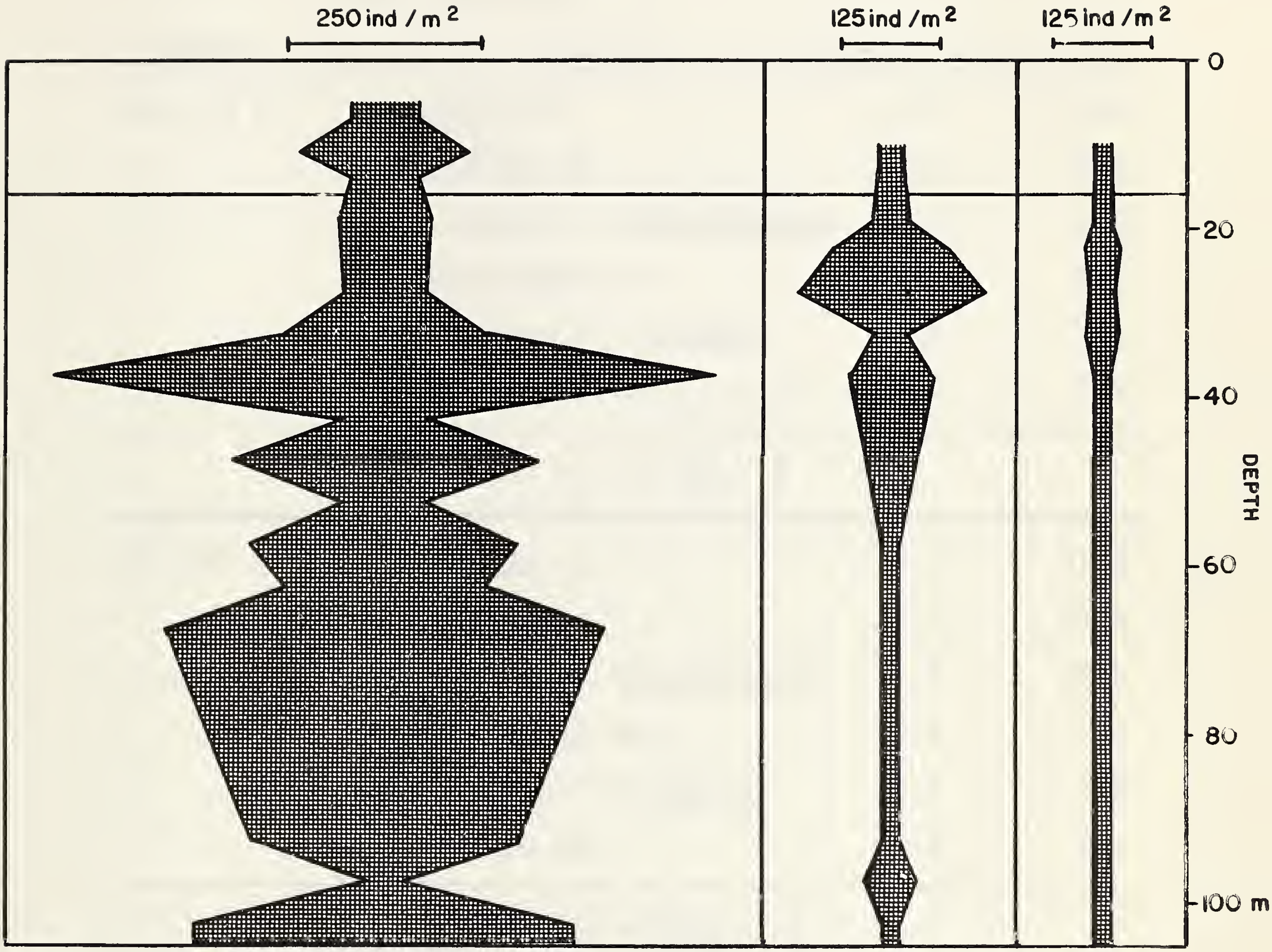
Tables XXXIII and XXXIV give the percentage abundances of the chironomid species for the various depth zones in Upper and Lower Kananaskis Lake.

Average bathymetrical distribution of *Tendipes* sp. (FIG. 74.), *Procladius* nr. *culiciformis* (FIG. 75.), and *Tanytarsus* sp. (FIG. 76.) in Upper Kananaskis Lake.



74. 75. 76.

Average bathymetrical distribution of _Trichocladius_ sp. (FIG. 77.), _Calopsectra_ nr. _confusa_ (FIG. 78.), and Diamesinae sp. (FIG. 79.) in Upper Kananaskis Lake.



77.

78.

79.

Table XXXIII. The percentages of the different species of chironomids for the various depth zones in Upper Kananaskis Lake during 1961 and 1962.

Depth	Species	Average Nos.	%
12.5-14 m	Tendipes sp.	27.0	45.8
	Tanytarsus sp.	20.5	34.7
	Procladius nr. culiciformis	5.0	8.5
	Trichocladius sp.	4.0	6.8
	Calopsectra nr. confusa	1.5	2.5
	Diamesinae sp.	1.0	1.7
	Total no. of spp. 6		
18.5-20 m	Tanytarsus sp.	28.0	44.9
	Tendipes sp.	17.6	28.2
	Procladius nr. culiciformis	7.8	12.5
	Trichocladius sp.	5.5	8.8
	Calopsectra nr. confusa	2.2	3.5
	Diamesinae sp.	1.3	2.1
	Total no. of spp. 6		
20.5-25 m	Tanytarsus sp.	25.5	41.0
	Tendipes sp.	15.1	24.3
	Procladius nr. culiciformis	7.4	11.9
	Calopsectra nr. confusa	7.1	11.4

continued

Table XXXIII. (continued).

Depth	Species	Average Nos.	%
20.5-25 m	*Trichocladius* sp.	5.1	8.2
	Diamesinae sp.	2.0	3.2
	Total no. of spp. 6		
25.5-50 m	*Trichocladius* sp.	84.9	32.0
	Tanytarsus sp.	65.0	24.5
	Tendipes sp.	58.3	22.0
	Procladius nr. *culiciformis*	25.6	9.6
	Calopsectra nr. *confusa*	25.1	9.5
	Diamesinae sp.	6.5	2.4
	Total no. of spp. 6		
50.5-80 m	*Trichocladius* sp.	59.0	65.6
	Procladius nr. *culiciformis*	22.0	24.4
	Tendipes sp.	5.0	5.6
	Diamesinae sp.	2.0	2.2
	Tanytarsus sp.	1.0	1.1
	Calopsectra nr. *confusa*	1.0	1.1
	Total no. of spp. 6		

continued

Table XXXIII. (continued).

Depth	Species	Average Nos.	%
80.5-105 m	Trichocladius sp.	40.5	50.4
	Procladius nr. culiciformis	15.2	18.9
	Tanytarsus sp.	10.7	13.3
	Tendipes sp.	8.0	10.0
	Calopsectra nr. confusa	5.0	6.2
	Diamesinae sp.	1.0	1.2
	Total no. of spp. 6		

NOTE: Individuals of Tanytarsus nr. nigricans, and Pentaneura (melanops gp.) sp. present in small numbers.

Table XXXIV. The percentage of the different species of chironomids for the various depth zones in Lower Kananaskis Lake during 1961 and 1962.

Depth	Species	Average Nos.	%
2.5-12.0 m	_Calopsectra_ nr. _confusa_	197.7	42.0
	Tanytarsus nr. _nigricans_	98.0	20.8
	Tendipes nr. _riparius_	52.2	11.1
	Procladius nr. _culiciformis_	39.9	8.5
	Tendipes sp.	30.0	6.4
	Trichocladius sp.	21.5	4.6
	Tanytarsus sp.	12.0	2.6
	Diamesinae sp.	10.0	2.1
	Pentaneura (_melanops_ gp.) sp.	9.0	1.9
	Total no. of spp. 9		
14.5-16 m	_Tendipes_ sp.	35.5	40.9
	Trichocladius sp.	32.0	36.9
	Calopsectra nr. _confusa_	8.4	9.7
	Diamesinae sp.	3.2	3.7
	Tanytarsus sp.	2.6	3.0
	Tanytarsus nr. _nigricans_	2.2	2.5
	Procladius nr. _culiciformis_	1.8	2.1
	Pentaneura (_melanops_ gp.) sp.	1.0	1.2
	Total no. of spp. 8		

continued

Table XXXIV. (continued).

Depth	Species	Average Nos.	%
16.5-20 m	Tanytarsus sp.	53.3	35.0
	Tendipes sp.	42.1	27.7
	Procladius nr. culiciformis	31.2	20.5
	Calopsectra nr. confusa	15.0	9.9
	Diamesinae sp.	5.5	3.6
	Trichocladius sp.	2.0	1.3
	Tanytarsus nr. nigricans	2.0	1.3
	Pentaneura (melanops gp.) sp.	1.0	0.1
	Total no. of spp. 8		
20.5-30 m	Tendipes sp.	23.4	29.6
	Tanytarsus sp.	20.4	25.8
	Procladius nr. culiciformis	12.5	15.8
	Calopsectra nr. confusa	10.7	13.5
	Tanytarsus nr. nigricans	7.0	8.9
	Diamesinae sp.	4.0	5.1
	Trichocladius sp.	1.0	1.3
	#Pentaneura (melanops gp.) sp.	-	-
	Total no. of spp. 8		

continued

Table XXXIV. (continued).

Depth	Species	Average Nos.	%
30.5-40 m	Procladius nr. culiciformis	36.2	39.6
	Tendipes sp.	20.5	22.5
	Tanytarsus sp.	12.5	13.7
	Calopsectra nr. confusa	7.5	8.2
	Tanytarsus nr. nigricans	7.1	7.8
	Diamesinae sp.	4.0	4.4
	Trichocladius sp.	2.5	2.7
	Pentaneura (melanops gp.) sp.	1.0	1.1
	Total no. of spp. 8		

NOTE: Species indicated with #, although not recorded in the depth zone indicated thusly, are recorded in the zone below.

VII. DISCUSSION

A. General

The components of the macroscopic benthic faunal community, other than the chironomids, pisidia, and oligochaetes, are poorly represented. This is attributed primarily to the absence of macrophytes about the shore of the reservoirs; this in turn undoubtedly affects fish forms which normally feed on the large herbivorous and other types of insects and fauna characteristic of the littoral region of unregulated lakes. Such insects as members of the Plecoptera, Ephemeroptera, Dytiscidae, etc., which generally form a major portion of the diet of certain of the fishes found in these reservoirs, are not available in appreciable numbers. Chironomids, which are relatively abundant in the reservoirs, are available to fish such as trout and whitefish, as pupae and imagoes and much less available during the remainder of their life cycles. Suckers inhabiting the reservoirs are more able to utilize the chironomid larvae due to their method of feeding and hence would be less affected by lack of a stable littoral region. Studies by Grimås (1961) and Nillson (1961) on the bottom fauna and the fishes in Lake Blåsjön have shown that large numbers of chironomid larvae do not insure large numbers of pupae and imagoes becoming available to the fish. In Blåsjön it was noted that a very intense hatching of

chironomids occurs in the regulated region of the lake and much of the energy of the food chain is lost to the lake by the inability of the fish to fully utilize the chironomids during this short, intense hatching period. This was in contrast to the more uniform hatching of the various chironomid species throughout the year in unregulated lakes in the same region.

In Barrier Reservoir there has been a reduction in the initial hegemony of the chironomids in relation to the other benthic forms immediately following impoundment. Still, the chironomids remain the dominant form comprising the benthic fauna. There has been a general increase in the standing crops of bottom fauna since the period 1947 to 1949, but it does not equal the amounts of standing crops found in lakes with stable littoral regions. Drawdown, with its supression of a productive littoral region, does not allow the development of a littoral maximum in abundance of bottom fauna, this littoral maximum being characteristic of unregulated environments. This absence of a littoral maximum is observed in the three reservoirs studied. The maximum abundance of bottom forms in Barrier Reservoir occurs in the 10.5 - 15 metre zone; in Upper Kananaskis Lake the maximum occurs in the 20.5 - 35 metre zone; in the Lower Kananaskis Lake the maximum occurs in the 10.5 - 15 metre zone. All of these zones are below the upper littoral region. Thus,

it appears that a major effect of regulation in these lakes is the suppression of a littoral maximum and with highest productivity below the region subject to direct water level fluctuation. The phenomenon is analagous to the situation in Lake Blåsjön which has a fluctuation in water level of six metres, and develops a maximum immediately below this level. However, the situation is exaggerated in Barrier Reservoir and Upper and Lower Kananaskis Lakes where fluctuation affects depths of 10 metres, 16 metres, and 14 metres respectively. As Grimås (1961) points out from a comparison of Lake Blåsjön with Lake Ankarvattnet, not only the region directly subject to fluctuation, but in addition, all depths of the lake experience qualitative as well as quantitative reductions of benthic forms. This pattern has probably occurred in Upper and Lower Kananaskis Lakes, though sufficient data are not available to make quantitative assessments. Barrier Reservoir is characterized by a qualitatively impoverished benthic fauna, never having attained a littoral fauna such as exists in unregulated lakes.

It is the chironomids which adapt most readily to the effects of regulation. The sudden increase in the numbers of chironomids relative to the entire benthic fauna occurred in Lower Kananaskis Lake immediately subsequent to regulation and initially Barrier Reservoir had a chironomid population consisting of approximately 98% of the total bottom fauna.

The pisidia and oligochaetes later achieved appreciable numbers but of a much lower order than for the chironomids. After 15 years of regulation it is only the chironomids which utilize the region subject to fluctuation in appreciable numbers. One factor favoring exploitation of this region by the chironomids is the vagility of the adults of this group. The larvae can enter unfavorable aquatic regions via the aerial adults without having to migrate from favorable through relatively unfavorable regions.

Much of the exposed region becomes suitable for the majority of the benthic forms following spring run-off and is likely repopulated from deeper regions following submersion. However, the lowering of the water level several months later again exposes this region. It is also under these conditions of exposure that the chironomids are best able to survive.

Thus, a general picture develops for the vertical distributions of the major components of the benthos in the three reservoirs: dominance of all depth zones by chironomids, with a tendency to less dominance with increasing depth; molluscs are present in significant numbers only below the drawdown limit, and down to all depths in Upper and Lower Kananaskis Lakes, and down to approximately 20 metres in Barrier Reservoir; oligochaetes follow no simple pattern either vertically or annually for the three reservoirs.

Although molluscs become reduced subsequent to regulation of lakes, the effect of this process may perhaps only be markedly produced in the zone subject to direct fluctuation. While the overall percentage of molluscs is much less following regulation when all depth zones are combined (cf. Rawson, 1958; Miller, 1954), the reduction is less apparent when the lake is divided into various depth zones.

The amount of productivity, using standing crops of bottom fauna as an index, for the three reservoirs increases from Upper Kananaskis Lake ---- Lower Kananaskis Lake ---- Barrier Reservoir. Investigations during the period 1947 and 1949 (Rawson, 1948; Nursall, 1952) arrived at the order of increasing productivity as Barrier Reservoir ---- Upper Kananaskis Lake ---- Lower Kananaskis Lake. At present the three reservoirs are subject to similar effects of fluctuation of water levels, though at different periods of the year, and this factor of fluctuation being relatively constant, the morphometric and edaphic factors lend themselves to suggest the present order of productivity of bottom fauna. Decreasing depth from Upper Kananaskis Lake ---- Lower Kananaskis Lake ---- Barrier Reservoir, with increasing total dissolved solids content in going from Upper Kananaskis Lake ---- Lower Kananaskis Lake ---- Barrier Reservoir; these factors would favor the order of increasing productivity

as observed during this study. It is of interest to note the situation regarding production of plankton in the three reservoirs; the order of increasing productivity, measured by comparing average standing crops of plankton, was approximately 10, 18, and 33 kgm/ha respectively for Barrier Reservoir, Upper Kananaskis Lake, and Lower Kananaskis Lake during the period 1947 - 49 (Nursall, 1952). A volumetric analysis of plankton during the present study indicates a similar pattern; a ratio of 0.2:1.5:2.0 for Barrier Reservoir, Upper and Lower Kananaskis Lakes respectively. The plankton productivity may well be affected by the light penetration which is least for Barrier Reservoir and greater for both Upper and Lower Kananaskis Lakes.

B. Chironomid fauna

A chironomid population, depauperate as regards the number of species, is evidenced in regulated lakes; this is the situation in the reservoirs examined during the present study. 21 species are recorded from Barrier Reservoir, with eight and nine species from Upper and Lower Kananaskis Lakes respectively. The latter two figures perhaps indicate inadequate sampling for determination of the species composition of these two reservoirs; however, it is felt that sufficient sampling has been done in Barrier Reservoir to give an accurate picture of the species composition.

Data are not available to indicate what the species composition was during previous investigations on these reservoirs, and hence, comparisons before and after regulation cannot be made. However, data from the Swedish lakes, Blåsjön and Ankarvattnet suggest trends which might be expected for reservoirs in general. A striking example is offered from Blåsjön where the original number of species, 85, decreased to 27 following regulation; similar reductions in species numbers have likely occurred in Upper and Lower Kananaskis Lakes.

The climatically based faunistical type-series has been offered by Brundin (1958), with the ultra-oligotrophic lakes indicative of arctic environments, and the ultra-eutrophic lakes characteristic of the equatorial lowlands. The change in balance of species in passing from one climatic extreme to the other can also be observed when going from low to high altitudes within a given region. Grimås (1961) suggests that the conditions outlined for natural environments are accentuated in regulated lakes; he states "... changes in the balance between the chironomid species and the reduction in the number of species which can be traced within the subarctic region with increasing altitude and with the climatic changes connected with it find their final expression in the regulated lake". This situation results in predominance of Orthocladiinae and Tanytarsini, with a lesser portion

of the fauna consisting of Chironomini and Tanypodinae.

It was predicted that this general trend would be followed in Barrier Reservoir (Nursall, 1952) with Tanytarsini becoming the preponderant group. Contrary to expectations the Chironomini have become the dominant group, in particular Tendipes sp., which dominates much of the lake.

A major focal point in the bathymetric distribution of chironomid species in regulated lakes is the drawdown limit. Lakes in general have the greatest number of individuals in areas with the greatest number of species. This condition exists in Lake Ankarvattnet, Lake Blåsjön, and Barrier Reservoir. However, the area with the greatest number of species is the upper littoral in Ankarvattnet while it is the region immediately below the drawdown limit in Blåsjön and Barrier Reservoir. This latter situation is comparable as regards the number of individuals for Upper Kananaskis Lake, but in Lower Kananaskis Lake maximal numbers occur above the drawdown limit; in part, the discrepancy in Lower Kananaskis Lake lies in the inadequate sampling of the regions immediately above and below the drawdown limit. That the maximal numbers occur below the drawdown limit in the Upper Kananaskis Lake, which also was inadequately sampled, is probably fortuitous. More extensive sampling of these regions in Upper and Lower Kananaskis Lakes might confirm the expected pattern of maximal numbers below the drawdown limit.

C. Suggestions for further study

While a detailed picture exists for the composition of the macroscopic bottom fauna in Barrier Reservoir, further studies could elucidate the contributions to the overall food chain of the reservoir as provided by the various benthic components. Differences are known to exist between regulated and unregulated lakes in production dynamics: it has been established that chironomids are available as prey to certain fish species mainly during the period of hatching, as pupae and imagoes (Nillson, 1955) and that in regulated lakes such as Blåsjön, for example, uneven distribution of chironomids spatially and temporally, results in greater losses of energy of the food chain than in unregulated lakes which have a more evenly distributed hatching regime. Studies of this sort would entail hatching experiments over the various depth zones in the reservoir. These might well augment data regarding changes in the balance among fish species occurring in the reservoir.

Detailed analysis of the contents of fish stomachs should accompany bottom fauna analysis. Assman (1961) has shown differences in the ability of certain fish groups to utilize the non-hatching chironomids; carp significantly reduced the biomass of chironomids in experimental enclosures, while goldfish little affected biomass in the same experiment. This in part may account for the present success of suckers

in the reservoirs studied (Nelson, 1962).

A more intensive investigation of Upper and Lower Kananaskis Lakes would be of interest, as they are subject to more violent fluctuations in water level than is Barrier Reservoir, and also drawdown occurs at different periods of the year in all three reservoirs. Upper Kananaskis Lake would be of special interest as it includes depths of over 100 metres.

Complete identification of larvae, pupae, and adults of the chironomid species should be attempted, through the rearing of the larvae, and by making comparisons of cast larval and pupal skins with the adults.

VIII. SUMMARY AND CONCLUSIONS

1. Three regulated bodies of water, Barrier Reservoir, Upper Kananaskis Lake, and Lower Kananaskis Lake, were investigated during 1960 - 1963 to elucidate the form and distribution of the macroscopic benthic fauna.

2. The benthic fauna of each is dominated by chironomid larvae, molluscs, and oligochaetes, roughly in that order.

3. All three reservoirs lack a littoral maximum in numerical abundance of benthic organisms, with maximal abundance occurring in the vicinity of the drawdown limit.

4. Relative productivity of benthic organisms in the reservoirs appears related to edaphic and morphometric features primarily, with increasing depth and decreasing total dissolved solids, yielding lesser amounts of benthic fauna.

5. The amount of productivity in Barrier Reservoir has increased since the 1947 - 1949 investigation. Still, the amount of productivity is much less than could be expected for an unregulated lake under similar conditions.

6. The region of highest productivity in Barrier Reservoir occurs in a small area of the north-south arm of the reservoir, lying between the corner of the reservoir and transect XI and designated as region B for this study.

7. The initial preponderance of chironomid larvae in Barrier Reservoir and Lower Kananaskis Lake, in relation to the total benthic fauna, has been reduced after a period of 'stabilization', but dominance by the chironomids is still apparent.

8. A depauperate chironomid fauna exists in the three reservoirs, as regards the number of species. Barrier Reservoir has 21 species, Upper and Lower Kananaskis Lakes have eight and nine species respectively. An unexpected proportion of the Tribe Chironomini exists, especially in Barrier Reservoir; the extent to which this tribe occurs has not been reported for other regulated bodies of water exhibiting oligotrophy-typical characteristics.

9. The greatest average number of species of chironomids in Barrier Reservoir lie immediately below the lower limit of drawdown.

10. Chironomid larvae appear best suited within the fauna to tolerate regulated conditions, being found almost

exclusively in the region subject to direct fluctuations in water level, and are dominant in all other regions. During extended periods of drawdown, chironomid larvae continue to survive in the exposed regions, for periods of up to at least 85 days duration, with the larger larvae most tolerant of these conditions.

11. The major components of the benthic fauna in Barrier Reservoir are most affected by drawdown and by the amounts of allochthonous nutrient material available, as indicated by their numerical abundance and distribution.

IX. LITERATURE CITED

Assman, A. V. 1961. Changes in the accessibility of Chironomidae larvae when eaten by fish. Referat. Zhur., Biol. No. 20D267., from Biol. Abs., 1962. (39): Abst. 635.

Brundin, L. 1948. Uber die metamorphose der Sectio Tanytarsariae Connectentes. Ark. f. Zool. 41: 1-22.

----------. 1951. The relation of O_2-microstratification at the mud surface to the ecology of the profundal bottom fauna. Inst. Freshw. Res. Drottningholm, Rept. 32: 32-42.

----------. 1958. The bottom faunistical lake type system and its application to the southern hemisphere. Moreover a theory of glacial erosion as a factor of productivity in lakes and oceans. Verh. internat. Ver. Limnol. XIII: 288-297.

Grimås, U. 1961. The bottom fauna of natural and impounded lakes in Northern Sweden (Ankarvattnet and Blåsjön). Inst. Freshw. Res. Drottningholm, Rept. 42: 183-237.

Johannsen, O. A. 1937a. Aquatic Diptera. Part III. Chironomidae: Subfamilies Tanypodinae, Diamesinae, and Orthocladiinae. Mem. 205. Cornell Univ. Agric. Exp. Stn.

---------------. 1937b. Aquatic Diptera. Part IV. Chironomidae: Subfamily Chironominae. Mem. 210. Cornell Univ. Agric. Exp. Stn.

Miller, J. 1914. A field method for determining dissolved oxygen in water. _J. Soc. Chem. Ind._, 33 (4): 185-186.

Miller, R. B. 1954. Effect of the Pocaterra power development on Lower Kananaskis Lake. Rept. to Alberta Dept. of Lands and Forests. 11 pp.

---------, and M. J. Paetz. 1959. The effects of power, irrigation, and stock water developments on the fisheries of the South Saskatchewan River. _Can. Fish. Cult._, 25: 1-14.

Mortimer, C. H. 1956. The oxygen content of air-saturated fresh waters, and aids in calculating percentage saturation. _Mitt. int. Ver. Limnol._ 7 pp.

Nelson, J. S. 1962. Effects on fishes of changes within the Kananaskis River System. M. Sc. Thesis. University of Alberta. 107 pp.

Nillson, N.-A. 1955. Studies on the feeding habits of trout and char in north Swedish lakes. _Inst. Freshw. Res. Drottningholm_, Rept. 36: 163-225.

-------------. 1961. The effect of water-level fluctuations on the feeding habits of trout and char in the Lakes Blasjon and Jormsjon, North Sweden. _Inst. Freshw. Res. Drottningholm_; Rept. 42: 238-261.

Nursall, J. R. 1949. Ecological changes in the bottom fauna in the first two years of the Barrier Reservoir. M. A. Thesis. University of Saskatchewan. 47 pp.

Nursall, J. R. 1952. The early development of a bottom fauna in a new power reservoir in the Rocky Mountains of Alberta. Can. J. Zool., 30: 387-409.

-------------. 1961. Investigations on the Kananaskis River May-Sept. 1961. 1. General account. Alta. Biol. Stn. Rpt. #12, pp. 57-62.

Rawson, D. S. 1930. The bottom fauna of Lake Simcoe and its role in the ecology of the lake. Pub. Ont. Fish. Res. Lab. No. 40. 183 pp.

------------. 1937. Biological examination of the Kananaskis Lakes, Alberta. Unpub. Rept. to Alberta Dept. of Lands and Mines. 12 pp.

------------. 1948. Biological investigations on the Bow and Kananaskis Rivers. Unpub. Rept. to Calgary Power Co. and Calgary Fish and Game Association. 72 pp.

------------. 1955. Morphometry as a dominant factor in the productivity of large lakes. Proc. Int. Assoc. Limnol. 12: 164-175.

------------. 1958. Indices to lake productivity and their significance in predicting conditions in reservoirs and lakes with disturbed water levels. Investigation of fish-power problems; University of British Columbia. pp. 27-42.

Roback, S. S. 1957. The immature tendipedids of the Philadelphia area. Monog. Acad. Nat. Sci. Philadelphia, No. 9. 148 pp.

Thomas, R. C. 1955. A report on conditions in the Kananaskis watershed in early June, 1955. Unpub. Rept. to Alberta Dept. of Lands and Forests. 12 pp.

------------. 1957. Effects of the Pocaterra power development on Lower Kananaskis Lake. Unpub. Rept. to Alberta Dept. of Lands and Forests. 12 pp.

X. APPENDIX

KEY TO THE IMMATURE CHIRONOMIDS OF BARRIER RESERVOIR

1. Larva with moveable case; labial plate with 13 teeth, central tooth light, laterals dark; paralabials as in Plate 1 (fig. 1)........ Stempellinella nr. brevis (Edw.)
   Larva without moveable case; labium and paralabials with different combination of characters 2

2. Lingua and super-lingua dark, well developed; basal antennal segment elongate Plate I (fig. 9); paralabial combs present 3
   Lingua and super-lingua not well developed or absent; basal antennal segment not as elongate as above; paralabial combs absent 4

3. Lingua of hypopharynx with center tooth distinctly shorter than first laterals Plate I (fig. 7); super-lingua bifurcate Plate I (fig. 8) .... Pentaneura (melanops gp.) sp.
   Center tooth of lingua not distinctly shorter than first laterals Plate II (fig. 10); super-lingua scale-like Plate II (fig. 11) ... Procladius nr. culiciformis (L.)

4. Dorsal hump on penultimate segment; petiole of lauterborn organ approximately 3 X length of last three antennal segments; paralabials elongate and meet near midline

Plate II (fig. 14) ... _Calopsectra_ nr. _confusa_ (Mall.)

Not as above 5

5. Median tooth distinctly trifid Plate III (figs. 17, 20); ventral gills present on segment 11 6

Median tooth trifid or otherwise; no ventral gills on segment 11 7

6. With caudo-lateral process on segment 10; both pairs of gills on segment 11 shorter than prolegs .... _Tendipes_ (_T._) _attenuatus_ (Walk.)

No caudo-lateral process on segment 10; both pair of ventral gills on segment 11 long Plate III (fig. 21) .... _Tendipes_ (_T._) nr. _riparius_ (Meig.)

7. Medial tooth trifid; fourth antennal segment longer than third; antennal ratio 80:16:6:8:5..._Tendipes_ sp.?

Median tooth not as above or lacking; antennal segments with different combination of characters 8

8. Labium with 16 teeth; first lateral teeth of labium projecting Plate IV (fig. 25); eye spots separated and large Plate V (fig. 27); anal gills tapering ... . _Tanytarsus_ nr. _nigricans_ (Joh.)

With other combination of characters 9

9. Labium with 14 teeth; mandible with an apical,

two laterals, and a dorso-mesal tooth Plate V (fig. 32); antennal ratio 28:7:6:8:3, with the blade extending to tip of fourth antennal segment ... . Polypedilum (fallax group)

With other combination of characters 10

10. Center of labium clear, flanked by a pair of dark lateral teeth Plate VI (fig. 36); first antennal segment shorter than remainder of segments; mandible with long apical and five lateral teeth Plate VI (fig. 34); single eye, with distinct collar between head and thorax Plate VI (fig. 33) .... Diamesinae sp.?

With other combination of characters 11

11. Labial plate with light arched toothless medial area flanked by five dark teeth Plate VI (fig. 37); premandibles comb-like Plate VI (fig. 39) ... . Cryptochironomus nr. fulvus (Joh.)

With other combination of characters 12

12. Labial plate strongly arched, with seven lateral teeth Plate VII (fig. 40); apical tooth of mandible long, with two laterals; first antennal segment twice as long as remainder of segments; paralabials clear and sinuate Plate VII (fig. 40) ... . Prodiamesa (Monodiamesa) sp.

With other combination of characters................ 13

13. First laterals of labial plate trifid Plate VII (fig. 44) and longer than medians; paralabial plate with a transverse row of forward projecting hairs .... <u>Prodiamesa</u> nr. <u>olivacea</u> (Meig.)
With other combination of characters 14

14. Median labial teeth small Plate VIII (fig. 45) and first laterals projecting beyond remainder; blade of antenna extending beyond tip of last antennal segment; antennal ratio 45:12:4:5:3; mandible as in Plate VIII (fig. 48); anal gills shorter than posterior prolegs .... <u>Tanytarsus</u> sp.
With other combination of characters 15

15. Light region posterior to median labial teeth Plate (fig. 49); mandible with long apical and four laterals; dorsal anal gills longer than ventral anal gills .... <u>Trichocladius</u> sp.?
With other combination of characters 16

16. Paralabials striate; center tooth of labium projecting and pointed Plate IX (fig. 52) ... . <u>Harnischia</u> nr. <u>nais</u> Townes
Paralabials striate, non-striate, or lacking; labium with other combination of characters 17

17. Paralabials striate; dome-shaped central region to labium flanked by seven laterals Plate IX (fig. 55); mandible as in Plate IX (fig. 57); Premandible as in Plate IX (fig. 56).. Harnischia nr. pseudotener (Goetgh.)
    With other combination of characters 18

18. Dome-shaped central region to labium, flanked by six or seven lateral teeth; mandible with enlarged base as in Plate X (fig. 59); premandible simple Plate X (fig. 60)........ Odontomesa nr. fulva (Kieff.)
    With other combination of characters 19

19. Central region of labium clear and triangular-shaped, flanked by five laterals Plate X (fig. 61); antennal ratio 12:5:1.5:1.5:1 .... Psectrocladius sp. 1
    With other combination of characters 20

20. Mandible with long, hooked apical tooth and four laterals Plate XI (fig. 66); antennal ratio 40:8:3:2; labium as in Plate X (fig. 64) ... . Psectrocladius sp. 2?
    With other combination of characters 21

21. Labium with more than 16 teeth; mandible with apical and four laterals, all dark; antenna as in Plate XI (fig. 69); eyes contiguous ... . Diamesa nr. nivoriunda (Fitch)

EXPLANATION OF FIGURES

PLATE I

Stempellinella nr. brevis (Edw.): 1--labial plate and paralabial plates; 2--mandible; 3--case of larva; 4--lateral view of caudal end; 5--lateral view of head region.

Pentaneura (melanops gp.) sp.: 6--lateral view of head region; 7--lingua of hypopharynx; 8--super-lingua of hypopharynx; 9--antenna.

PLATE II

Procladius nr. culiciformis (L.): 10--lingua of hypopharynx (variation of normal); 11--super-lingua of hypopharynx; 12--antenna; 13--paralabial comb.

Calopsectra nr. confusa (Mall.): 14--labium and paralabial plates; 15--antenna; 16--lateral view of head region.

PLATE III

Tendipes (Tendipes) attenuatus (Walk.) [= decorus Joh.] : 17--labial plate; 18--antenna; 19--lateral view of caudal end.

Tendipes (Tendipes) nr. riparius (Meig.): 20--labial plate; 21--lateral view of caudal end.

PLATE IV

Tendipes sp.?: 22--labial plate; 23--mandible; 24--antenna.

Tanytarsus nr. nigricans (Joh.): 25--labial plate; 26--antenna.

PLATE V

Tanytarsus nr. *nigricans* (Joh.): 27--lateral view of head region; 28--lateral view of caudal end; 29--mandible.

Polypedilum (*fallax* group): 30--labial plate and paralabial plates; 31--antenna; 32--mandible.

PLATE VI

Diamesinae sp.?: 33--lateral view of head region; 34--mandible; 35--antenna; 36--labial plate.

Cryptochironomus nr. *fulvus* (Joh.): 37--labial plate; 38--antenna; 39--premandible.

PLATE VII

Prodiamesa (*Monodiamesa*) sp.: 40--labial plate and paralabial plate; 41--mandible; 42--antenna; 43--lateral view of head region.

Prodiamesa nr. *olivacea* (Meig.): 44--labial plate and paralabial plate.

PLATE VIII

Tanytarsus (*Tribelos*) sp.: 45--labial plate; 46--antenna; 47--lateral view of caudal end; 48--mandible.

Trichocladius sp.?: 49--labial plate; 50--lateral view of caudal end; 51--mandible.

PLATE IX

Harnischia nr. *nais* Townes: 52--labial plate and paralabial plate; 53--mandible; 54--lateral view of head region.

Harnischia nr. *pseudotener* (Goetgh.): 55--labial plate and paralabial plate; 56--premandible; 57--mandible.

PLATE X

Odontomesa nr. *fulva* (Kieff.): 58--labial plate; 59--mandible; 60--premandible.

Psectrocladius sp. 1: 61--labial plate; 62--antenna; 63--mandible.

Psectrocladius sp. 2: 64--labial plate; 65--antenna.

PLATE XI

Psectrocladius sp. 2: 66--mandible.

Diamesa nr. *nivoriunda* (Fitch): 67--labial plate; 68--mandible; 69--antenna; 70--lateral view of head region.

PLATE I

PLATE II

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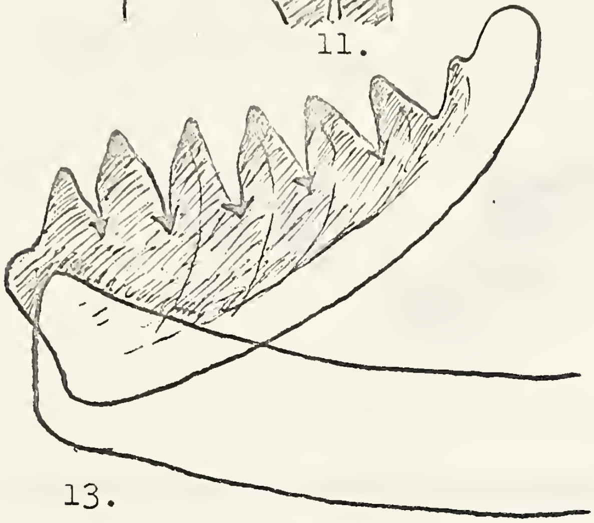
12.



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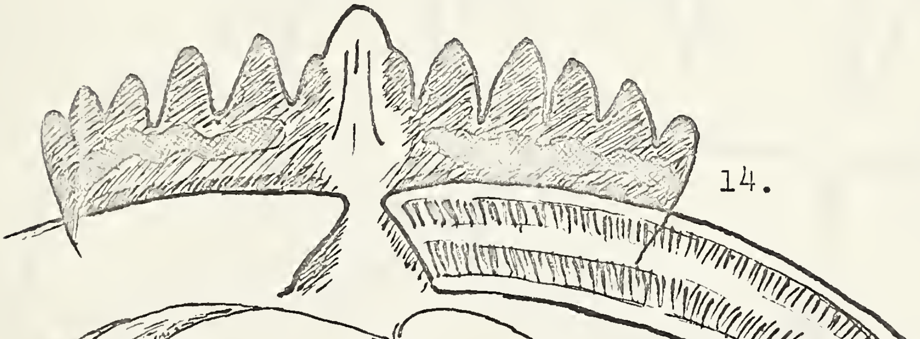

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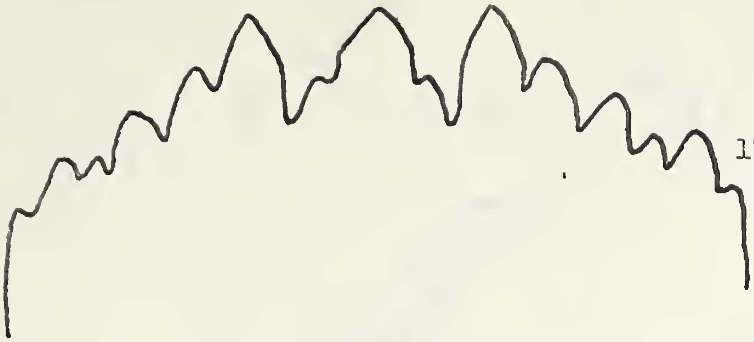

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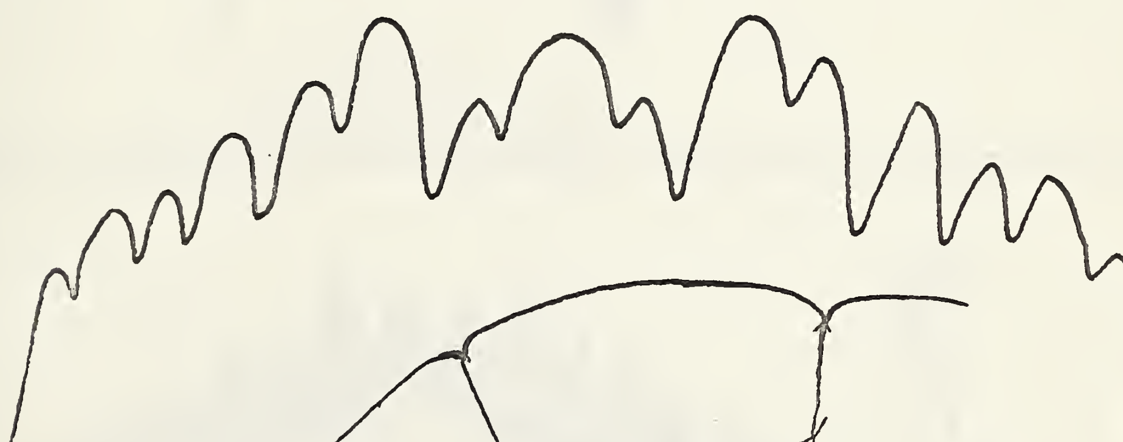

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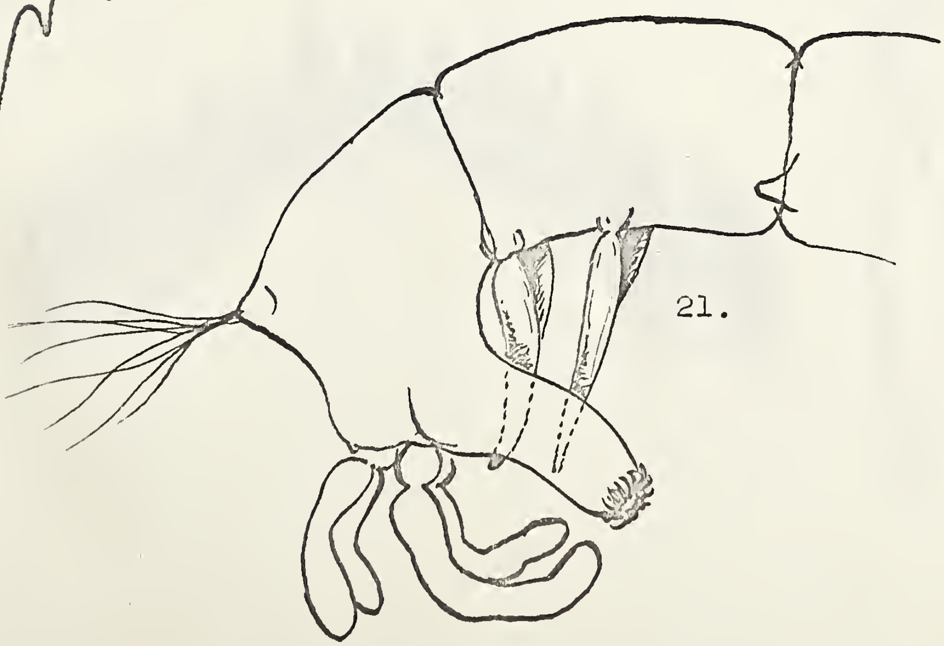

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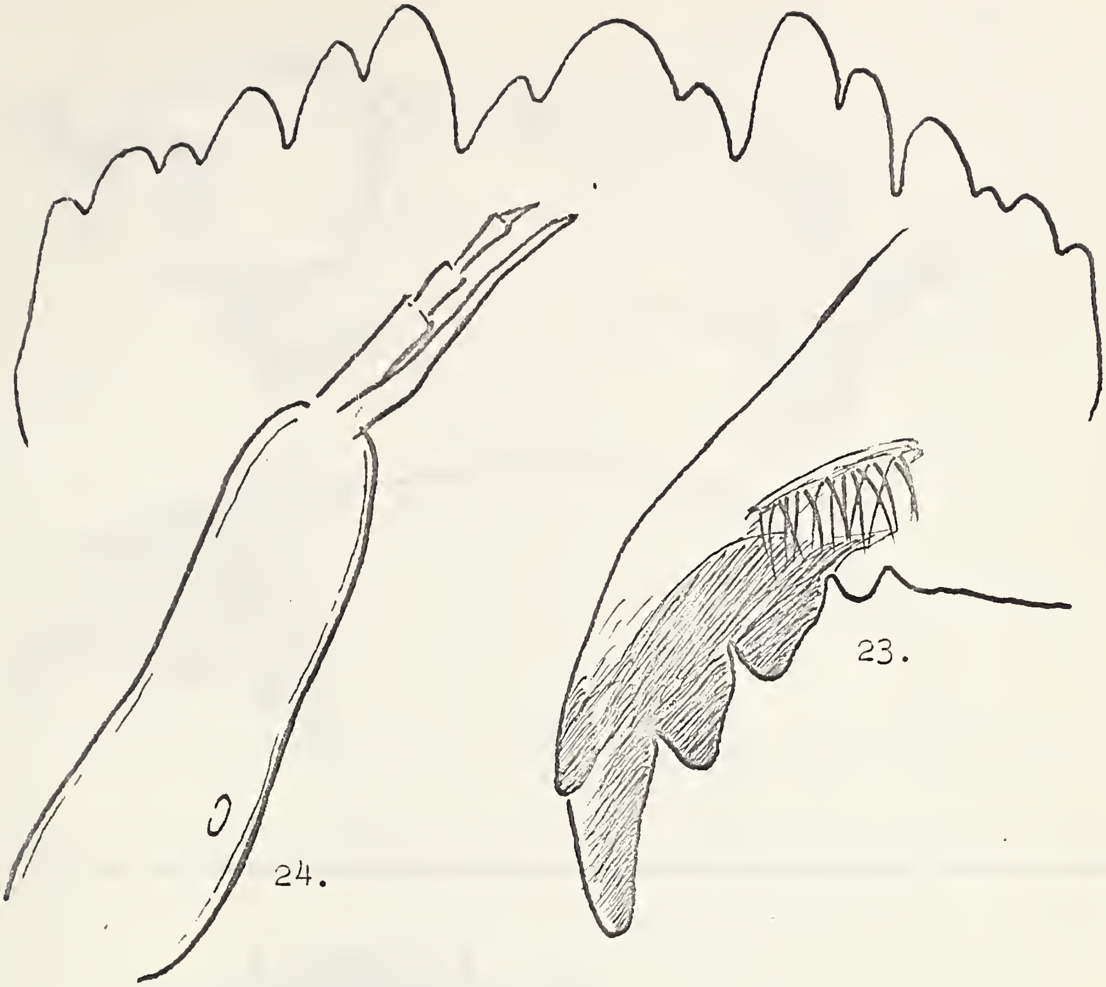

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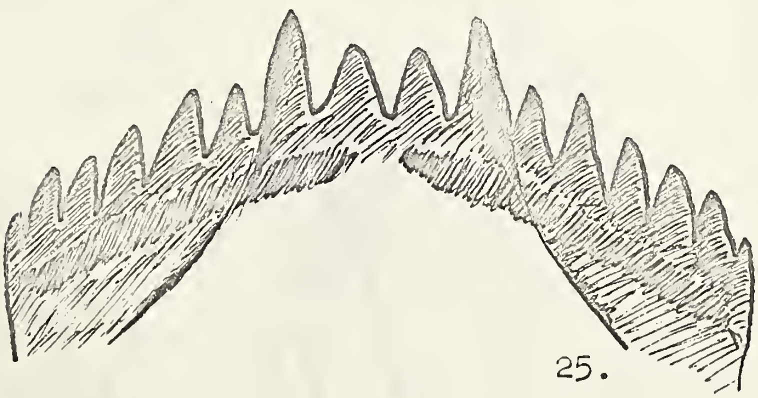

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PLATE VI

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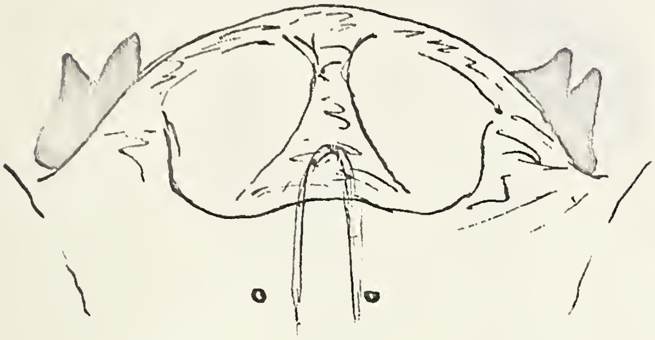

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PLATE VII

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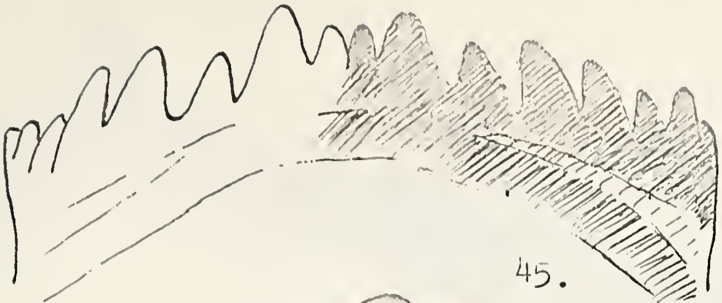
PLATE VIII



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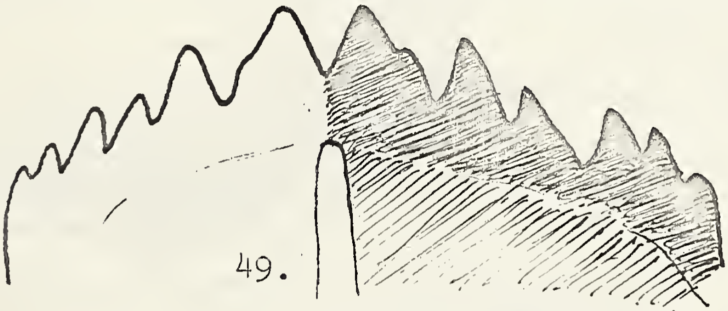

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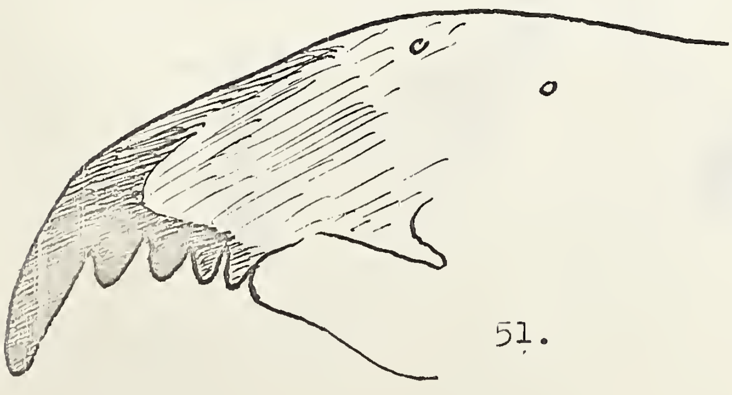

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52. 53. 54.

55. 56. 57.

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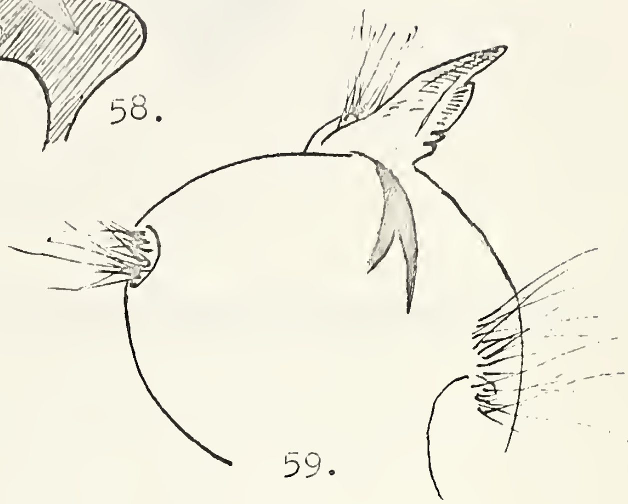

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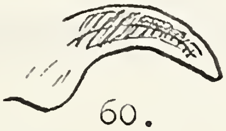

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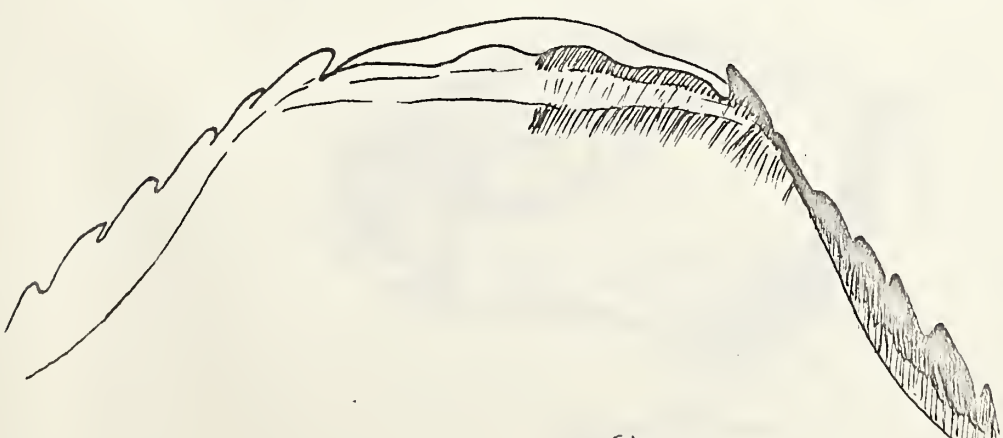

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PLATE XI

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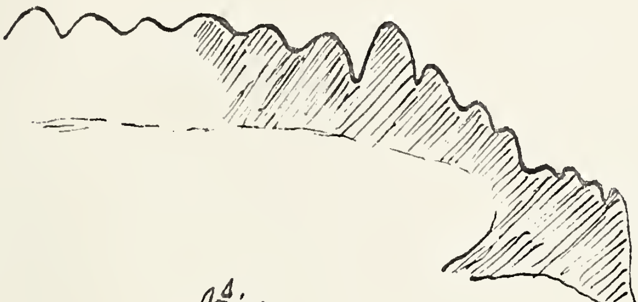

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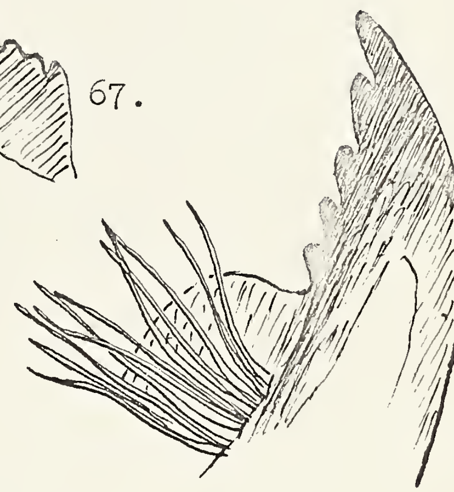

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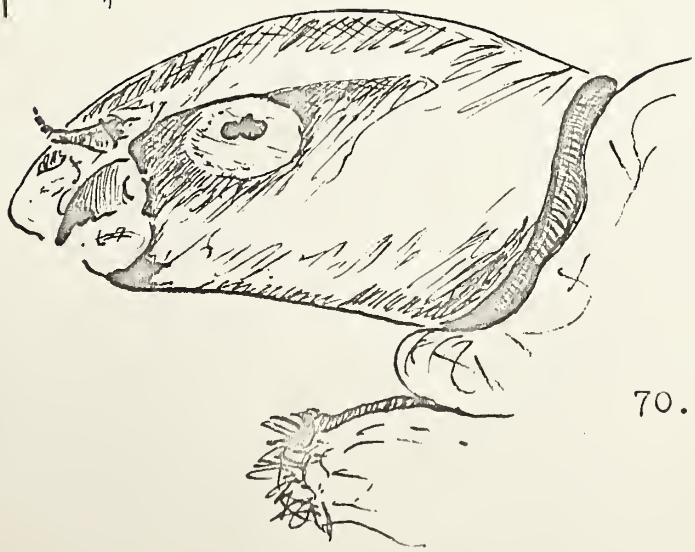

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